TECHNICAL SUPPORT DOCUMENT
PM_{10} SIP UAM-AERO
MODELING EFFORT
SALT LAKE COUNTY & UTAH COUNTY

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Preface

The State of Utah submitted revisions to the PM_{10} SIP for Utah County and Salt Lake County in 2002. These SIP revisions were required due to a lapse in transportation conformity budgets for both counties. At the time, the Utah Division of Air Quality (DAQ) initiated a "two-pronged" approach for the modeling to support the SIP changes; a CMB analysis similar to that used in the original SIP, and regional grid-based modeling using UAM-AERO. This document outlines the technical process that the DAQ used to complete the UAM-AERO base-case and performance evaluation. Although this UAM-AERO modeling was completed successfully, DAQ found that the CMB approach was sufficient to meet the SIP revision requirements and thus the UAM-AERO results were not submitted to EPA. The process and results outlined below lent significant understanding to the use of UAM-AERO, and regional models in general, and it will be used for the future PM_{10} Maintenance Plan submittal.

1.0 Description of Modeling System

1.1 Background

The state of Utah developed a State Implementation Plan (SIP) for PM_{10} in the early 1990's that was approved by EPA in 1994. This SIP targeted Utah's historical problem with secondary particulate formation during wintertime inversions along the Wasatch Front. Although there have been no violations of the PM_{10} NAAQS in the nonattainment areas since the SIP was implemented, Utah's Department of Transportation has shown that the next round of long-range transportation plans and transportation improvement plans, due in 2000 for Utah County and 2001 for Salt Lake County, will not be able to show conformity to the PM_{10} SIP for each of those counties. Much of this nonconformity is the result of changes to EPA's mobile emissions models that were used to establish emission budgets in the current SIP. Because the Utah Division of Air Quality (DAQ) is required to demonstrate conformity for Utah and Salt Lake Counties, DAQ is using this opportunity to develop a PM_{10} Maintenance Plan for these two counties. DAQ hopes that this Maintenance Plan will result in redesignation of Salt Lake and Utah Counties to attainment for PM_{10}.

Modeling tools have advanced in the years between the development of the current PM_{10} SIP in the late 1980's and today. The existing SIP is based on receptor modeling and county-wide roll-back of PM_{10}, SO_2, and NO_x. In consultation with EPA Region VIII, DAQ has decided to take a two pronged approach to the attainment demonstration for this new SIP/Maintenance Plan. This approach will consist of grid-based aerosol modeling approach using UAM-AERO and an observational model coupled with a speciated linear rollback and the Chemical Mass Balance (CMB) model. The attainment/maintenance demonstration will be based on the results of one or both of these models.

UAM-AERO, an urban-scale grid-based aerosol model developed by the California Air Resources Board will be used to analyze the airshed for one historical episode during 1996. Because there have been no violations of the PM_{10} NAAQS since 1995, this episode does not represent excessive PM_{10} concentrations. In addition, availability of PM_{10} data is sparse in the 1990's due to relatively clean air quality during this time period. Since aerosol modeling is still in its infancy, relative to photochemical ozone modeling, guidance on model performance evaluation is not available. For this reason UAM-AERO may be used in a relative sense only. That is to say that the modeling results may be used to inform and supplement a method of speciated linear rollback, rather than use the model results in a traditional modeled attainment test.

1.2 Objectives

The state of Utah is required to develop a plan to demonstrate that it is able to maintain ambient air quality conditions for PM_{10} below the federal 24-hour standard for specific years in the future for the nonattainment area. To aid in meeting the goals of this study DAQ contracted with Sonoma Technology, Inc. (STI) for the development of the emissions inventory, and for analysis of both input and output modeling data sets. DAQ contracted with the University of Utah Meteorology Department for development of highly resolved prognostic meteorological fields. DAQ provided the modeling expertise for the general development and running of UAM-AERO through a multi-phased effort to apply an aerosol grid model to the Wasatch Front area.

1.3 Choice of Models

UAM-AERO employing CB-IV chemistry was used as the aerosol model in the PM_{10} SIP modeling. UAM-AERO is an extension of the widely used photochemical model, the Urban Airshed Model (UAM), Version IV, which has been adapted to treat aerosol processes. DAQ chose to use this model because of extensive staff experience using UAM-IV for ozone analysis. The key feature of the UAM-AERO model is that it provides a common framework in which to evaluate relationships between ambient concentrations of both ozone and particulate matter (PM), and their precursor emissions. (Kumar and Lurmann, 1996; Lurmann, et al, 1997) Assistance with setup and evaluation of UAM-AERO was obtained from STI.

Given the complexity of the local mountainous terrain, in close proximity to two large bodies of water (Lake Utah and Great Salt Lake), DAQ used a combination of a prognostic meteorological model and a diagnostic wind model to develop the meteorological inputs to the UAM-AERO. Specifically, scientists at the University of Utah Department of Meteorology developed meteorological input data for the UAM-AERO using the Penn State/NCAR mesoscale model (MM5). STI developed modified wind fields using the Diagnostic Wind Model (DWM). The two results were then combined into one self-consistent set of meteorological fields.

Processing of the emissions data sets assembled for point, area, and mobile sources was accomplished through use of the Sparse Matrix Operator Kernel Emissions Modeling System (SMOKE). The emissions processing model takes the annual, county-wide emissions inventory prepared by DAQ and reformulates it for use in the air quality model. Because wintertime episodes will be modeled, estimates of biogenic emissions will not be included in the analysis. The emissions data sets were created and evaluated by STI in consultation with DAQ.

1.4 Overview of the Modeling Project

Since the early 1990's there have not been any major inversion episodes (stagnant conditions persisting for one to three weeks) in the Wasatch Front urban area. It is during stagnant conditions that PM_{10} builds up in the area and as the condition persists, more and more PM_{10} (especially secondary PM) accumulates causing ambient values to exceed the NAAQS. One 4-day episode was selected during February, 1996 as it has the highest ambient PM_{10} values during the previous five years. Although the meteorological database from 1996 is more limited than is currently available, there is a chemically speciated data set for some of the PM_{10} monitors on several of the episode days. In June of 1996 a wider network of meteorological observations became available, however, there have not been any candidate episodes to model since that time.

DAQ completed the UAM-AERO modeling project with full knowledge of the limitations of the model and our episode. The model results and model performance are discussed in detail in this Technical Support Document (TSD).

1.5 The Aerosol Dispersion Model (UAM-AERO)

The aerosol model used for the PM_{10} SIP modeling is the Urban Airshed Model with aerosol treatment employing SAPRC90 chemistry (UAM-AERO). The UAM-AERO is an Eulerian aerosol model that simulates the emission, transport, dispersion, chemical transformation, and removal of inert and chemically reactive species in the atmospheric boundary layer.

1.6 Chemical Mechanism in UAM-AERO

The particulate mechanism in UAM-AERO is described in the "User's Guide to the UAM-AERO Model" (Kumar and Lurmann, 1996) and in Lurmann, et al, 1997. UAM-AERO simulates the effects of emissions injection, horizontal and vertical transport and dispersion, dry deposition, and chemical reactions on atmospheric concentrations of particulate pollutants. The model quantifies the relationships between ambient PM concentrations and emissions of particles and of gaseous compounds that form secondary PM and/or affect the rate of secondary PM formation.

The emissions inputs to the model include six chemical components of particulates (elemental carbon, organic material, sulfate, sodium, chloride, and crustal material), and gaseous emissions of NO_x, SO_2, NH_3, VOC, and CO. The model predicts the following chemical components of PM as output: nitrate, sulfate, ammonium, sodium, chloride, elemental carbon, organic material, crustal material, and water.

UAM-AERO simulates the aerosol-size distribution as well as the chemical composition of the aerosols. Tracking aerosol size is important because the fate of particles in the atmosphere depends largely on their size. Particles grow and shrink in response to a number of physical processes and simulation of these dynamic processes is necessary to accurately predict the PM mass concentrations. In this modeling project, the only size bin used is the one for particles less than 10 µm in diameter.

UAM-AERO also has a mechanism to simulate the effect of the presence of fog on gas and aerosol species. When haze or fog exists, the model allows particles to grow to sizes larger than 10 µm. Particle growth and shrinkage are determined by the amount of water transferred to and from the aerosol based on the equilibrium concentrations estimated by SEQUILIB for specific relative humidity, temperature, and aerosol chemical composition. Deposition of fog droplets is calculated using the same procedures used for other particles. In addition, aqueous-phase chemical reactions are simulated using the gas-phase chemistry operator.

1.7 UAM-AERO Region Definition

The proposed UAM-AERO modeling domain (Figure 1-1) consists of a 33 x 56 grid (east-west by north-south) with a 4 km resolution. This region contains the bulk of the emissions in the greater Ogden-Salt Lake City-Provo region.

The following vertical grid structure is used:

- Five (5) vertical layers, two below the inversion and three above;
- A region top sufficiently high to contain all elevated point sources and the maximum inversion rise;

- A minimum cell height of 40 meters for layers 1 and 2 (below the inversion base); and
- A minimum cell height of 200 meters for layers 3 through 5 (above the inversion base).

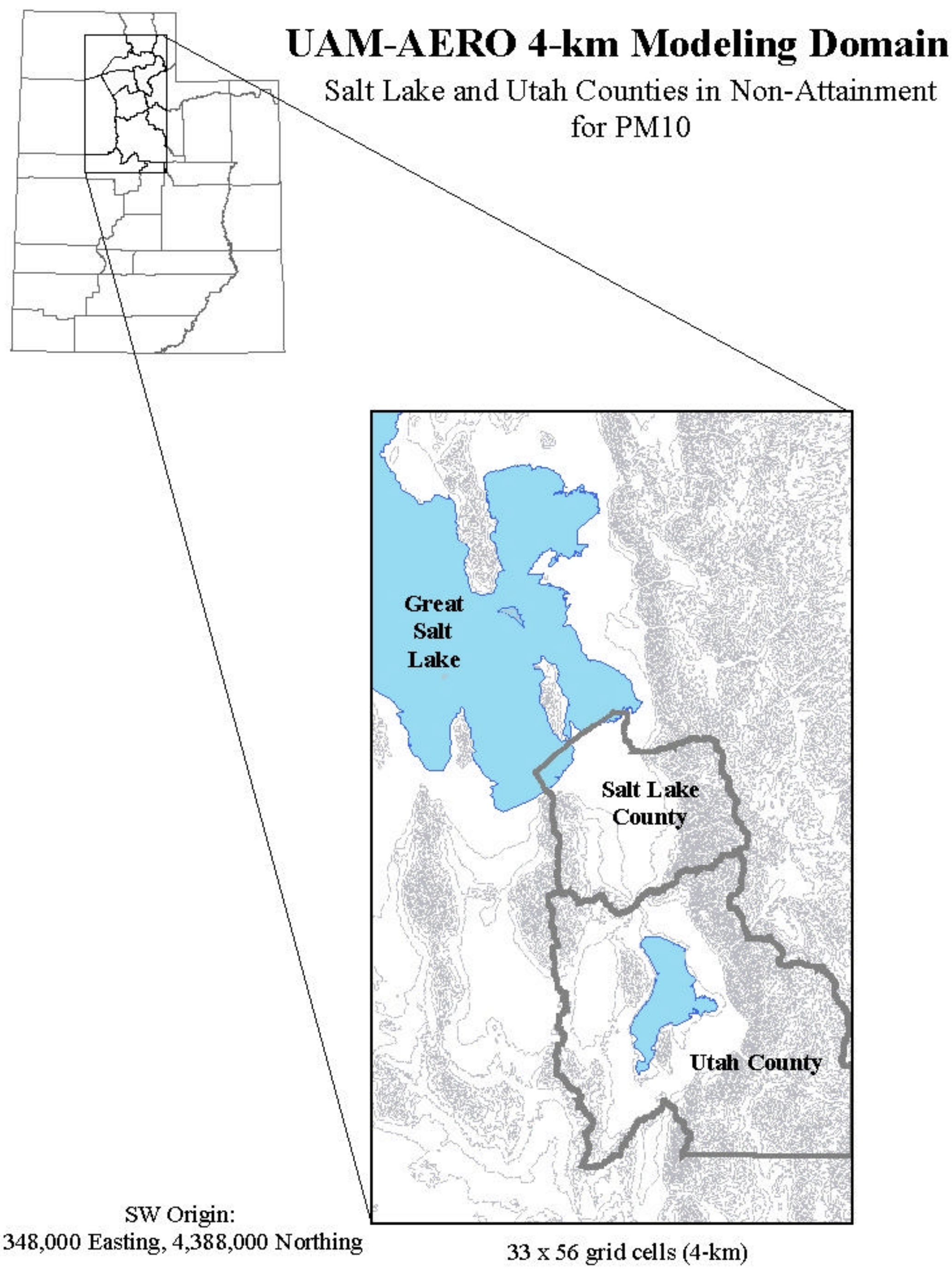


Figure 1-1. UAM-AERO 4-km modeling domain

2.0 Meteorological Modeling

2.1 Introduction

The meteorological model used to provide input to UAM-AERO was the Pennsylvania State University – National Center for Atmospheric Research mesoscale model (MM5). The development and results of this modeling effort are discussed in this section.

Because of a lack of inversion events in recent years, the case selected for testing PM_{10} control strategies occurred from 11-16 February 1996 and featured the highest PM_{10} levels observed in the five years prior to the development of the SIP. Unfortunately, the event occurred during a period when limited meteorological data was available. In particular, only limited surface observations were available outside of the Salt Lake Valley, and upper-level temperature and wind observations were collected only twice-daily at a single site (Salt Lake City). Because of the complexity of the local terrain, close proximity to two large bodies of water (Utah Lake and the Great Salt Lake), and a lack of observations, a mesoscale model simulation that incorporated data assimilation was used to provide meteorological input for the UAM-AERO. The remainder of this report describes the mesoscale model, accuracy of the 11-16 February 1996 simulation, and techniques used to provide input to UAM-AERO.

2.2 Data and Methods

To provide meteorological input for the UAM-AERO, a five-day simulation incorporating the assimilation of gridded analyses and point observations was run using the non-hydrostatic Pennsylvania State University – National Center for Atmospheric Research mesoscale model (MM5; Grell et al. 1994). The simulation featured four domains with horizontal grid spacings of 54, 18, 6, and 2 km (Fig. 1). The topography provided at 2-km grid spacing captures the general characteristics of northern Utah's topography, although the crest height, steepness, and individual canyons of the Wasatch, Oquirrh, and Stansbury Mountains are not fully resolved (cf., Figs. 2a, b). Fifty-five variably spaced full-sigma levels were used in the vertical, with an effective vertical resolution of ~10 mb from the surface to near crest level and ~30 mb in the middle to upper troposphere. Higher resolution was used below crest level to improve the simulation of low-level inversion and stable layers. The effective height of the lowest-level of the MM5 is ~35 m AGL.

Cloud and precipitation processes were parameterized using the Reisner-I scheme that allows for mixed-phase clouds (i.e., supercooled water) and includes bulk prognostic equations for water vapor, cloud water, rain water, cloud ice, and snow (Reisner et al. 1998). On the 54-km and 18-km domains, the Kain-Fritsch cumulus parameterization (Kain and Fritsch 1993) was used to represent sub-grid-scale moist-convective processes. Although precipitation was not observed over northern Utah during the 11-16 Feb 1996 event, the cloud microphysics and cumulus parameterizations are important since they affect the large-scale simulation and the prediction of cloud cover over the study area. Other parameterizations included the so-called Blackadar planetary boundary layer (Zhang and Anthes 1982), a five-layer soil model (Dudhia 1996), a cloud-interactive radiation scheme (Dudhia 1989), and an upper-radiative boundary condition (Klemp and Durran 1983).

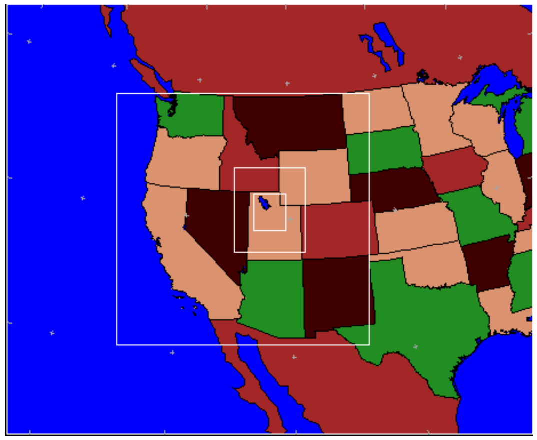
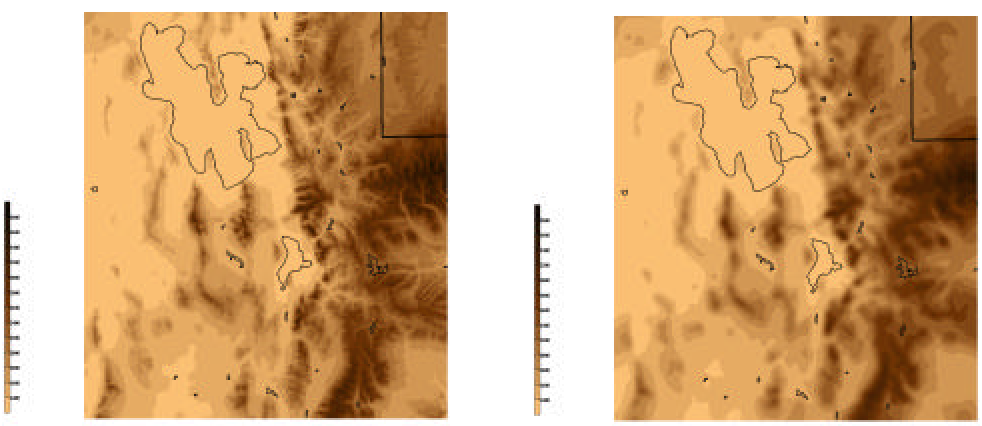


Figure 2-1. MM5 simulation domains

The simulation was initialized at 0000 UTC 11 February and integrated 132 h to 1200 UTC 16 February. This provided 7 h of model spinup prior to the start of the UAM-AERO at 0700 UTC 16 February. Initial and lateral boundary conditions were based on operational analyses from the National Centers for Environmental Prediction Eta Model, which were available every 12 h at a grid-spacing of 80 km and interpolated to MM5 grid points. Multiscale four-dimensional data assimilation was used throughout the simulation using a methodology similar to that employed by Stauffer and Seaman (1994). The assimilation technique used Newtonian nudging to relax the 54-km and 18-km domain simulations to Eta model gridded analyses, while 2-km domain forecasts were nudged to individual surface observations. The nudging coefficients listed in Table 1 were selected based on the spatial and temporal resolution of the gridded analyses, density of point observations, and the desire to limit error growth without overwhelming the development of mesoscale features.



(a) (b)

Figure 2-2. Topography of northern Utah
(a) Actual terrain at 30-sec resolution with station locations discussed in text. (b) Terrain from the 2-km domain. Elevation based on scale in (a).

Table 2-1. Nudging coefficients

Variable	54-km domain analysis nudging coefficients (no nudging in PBL)	18-km domain analysis nudging coefficients (No nudging in PBL)	2-km domain observation nudging coefficients
u,v	3x10-4 s-1	2x10-4 s-1	5x10-4 s-1
T	3x10-4 s-	2x10-4 s-1	no nudging
q	1x10-5 s-1	1x10-5 s-1	no nudging

Data used for model assimilation and validation included surface temperature, dewpoint, relative humidity, and wind observations collected by the National Weather Service/Federal Aviation Administration/Department of Defense (NOAA-NWS) observing network and the Utah Air Monitoring Center (AMC) of the DAQ (Fig. 2a). The NOAA-NWS data were collected hourly and represent 5-min averages, with temperature and dewpoint collected at 2-m AGL and wind at 10-m AGL. The AMC data were available hourly, represent hourly averages, and are more heterogeneous in terms of siting and height of the data collected. In some cases, the DAQ data was collected on or near buildings.

Evaluation of the model simulation was done both statistically and subjectively using the data described above. Statistical measures of model performance that are presented in this report include the bias error (BE),

$$BE = \frac{1}{N}\sum_{i=1}^{N} F - O$$

where F is the forecast value, O is the observed value, and N is the number of observations used for the validation. Also evaluated is the root-mean-squared (RMS) error, defined as

$$RMS = \sqrt{\frac{1}{N} * \sum_{i-1}^{N} (F - O)^{2}}$$

RMS error measures the typical size of model forecast errors and tends to give more weight to larger errors. Statistical measures presented in this paper cover the period of the UAM-AERO simulation from 0700 UTC 11 Feb - 0700 UTC 16 Feb 1996. A subjective model evaluation was also conducted and examined the accuracy of the large-scale forecast, simulated soundings at Salt Lake City International Airport, and simulated wind flow over northern Utah.

2.3 Results

a. Overall statistics

MM5 RMS errors averaged for the entire simulation are presented in **Table 2-2**. Averaged over all stations in the UAM-AERO domain, RMS errors for wind speed, the zonal wind component (U), and meridional wind component (V) were all less than 1.5 m s-1. Bias errors were also small (**Fig. 2-3**), indicating that the simulation did not systematically over-predict or under-predict near-surface wind speed. Neither bias nor RMS error grew substantially during the simulation. The only stations exhibiting large bias and RMS errors are Hill Field (HIF), where localized outflow from Weber Canyon was observed but was not resolved at 2-km grid spacing, and Provo (PVU), where simulated winds were stronger than observed (**Table 2-2**).

Temperature RMS errors averaged over the UAM modeling domain exceeded 3°C (**Table 2-2**). The primary contributor to these errors was large positive temperature biases during the night and early morning hours when the valley inversion was most intense (**Fig. 2-3b**). This resulted in a noticeable diurnal oscillation in the bias error with errors tending to be smallest during the afternoon and largest at night and during the early morning (**Fig. 2-3a**). The trend during the model simulation was for the warm bias to grow about 1°C, as indicated by the trend line depicted in Fig. 4a. Bias errors were largest over Utah County where simulated temperatures were much warmer than observed, resulting in large RMS errors, while bias and RMS errors were smallest over the northern Wasatch Front (**Table 2-2**, bias errors not shown).

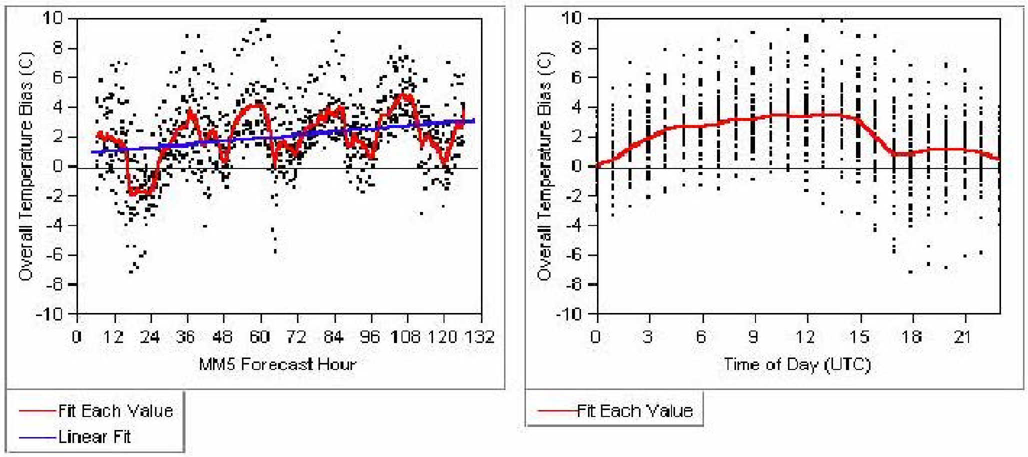
Table 2-2. Average MM5 RMS errors

Station(s)	Location	Temperature (c)	Dew Point (c)	Relative Humidity (%)	Zonal (U) Wind (ms-1)	Meridional (V) Wind (ms-1)	Wind Speed (ms-1)
ALL	UAM Domain	3.25	3.46	20.95	1.42	1.24	1.37
N. Wfrnt	N. Wfrnt	2.32	3.66	16.14	2.02	1.26	2.02
SL Valley	SL Valley	2.69	3.22	21.09	1.13	1.03	1.05
Utah Co.	Utah Co.	4.26	3.56	25.52	1.27	1.46	1.18
SLC	SL Valley	3.11	3.13	23.2	1.07	1.57	1.44
QAM	SL Valley	n/a	n/a	n/a	1.44	0.66	1.21
QB4	SL Valley	n/a	n/a	n/a	1	0.83	1
QCW	SL Valley	2.08	3.24	22.3	1.26	0.64	0.66
QHE	SL Valley	2.81	3.28	17.45	1.36	1.07	1.29
QMG	SL Valley	n/a	n/a	n/a	0.78	1	0.68
QNT	SL Valley	n/a	n/a	n/a	1.67	1.17	0.84
HIF	N. Wfrnt	2.74	4	16.3	3.1	1.29	3.14
OGD	N. Wfrnt	1.96	3.22	16.2	1.04	1.42	1.41
QBT	N. Wfrnt	n/a	n/a	n/a	1.7	1.11	1.74
QWT	N. Wfrnt	2.03	3.51	15.96	1.19	1.27	0.8
PVU	Utah Co.	5.93	3.33	26.1	1.26	1.55	1.68
QHG	Utah Co.	n/a	n/a	n/a	1.38	2.02	1.44
QLN	Utah Co.	3.04	3.76	24.95	1.09	1.09	0.62
QNP	Utah Co.	3.23	n/a	n/a	1.11	1.25	0.73
QWO	Utah Co.	n/a	n/a	n/a	1.48	1.22	1.11

As shown later in this section, the MM5 captured the general character of the inversion during this event, suggesting that the nocturnal warm bias was in part a reflection of limited vertical resolution of the simulation. Reducing the forecast 35-m temperature to the height of the observations (generally 2-m AGL) likely would have resulted in smaller bias errors.

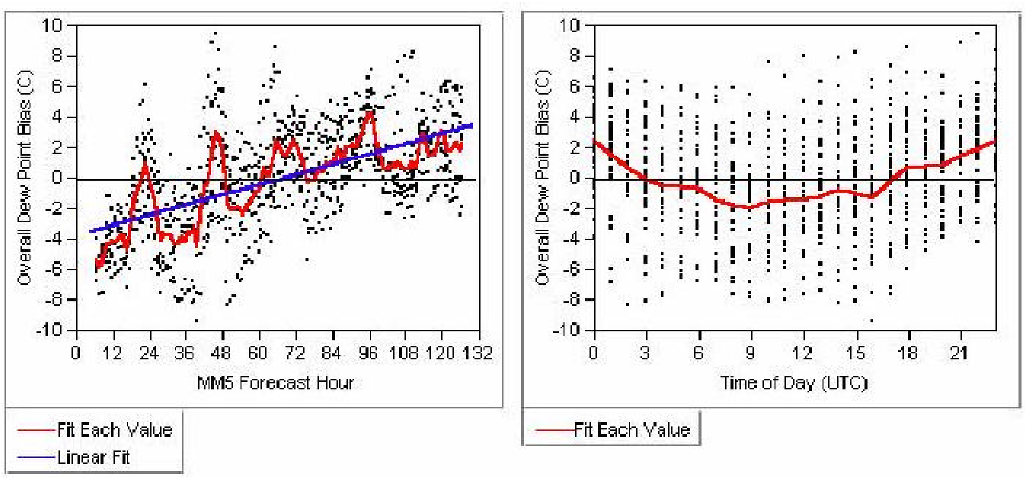
Dewpoint RMS errors averaged over the UAM modeling domain were ~3.5°C (**Table 2-2**), and like temperature, bias errors fluctuated diurnally (**Fig. 2-4a**). Simulated dewpoints tended to be too low overnight and in the early morning hours and too high during the late afternoon and evening (**Fig. 2-4b**). The simulation started too dry, gradually moistened over time, and eventually developed a positive moisture bias (**Fig. 2-4a**).

Relative humidity RMS errors averaged over the UAM domain were ~20% (**Table 2-2**). Relative humidity was generally lower than observed except during the late afternoon and early evening (**Fig. 2-5**). Removing the diurnal signal revealed a dry bias early in the simulation but little bias toward the end.



(a) (b)

Figure 2-3. Temperature bias error scattergrams
(a) As a function of forecast hour. (b) As a function of the time of day (UTC). Hourly-average indicated by red line. Linear fit vs. forecast hour in (a) indicated by blue line.



(a) (b)

Figure 2-4. Dew point bias error scattergrams
(a) As a function of forecast hour. (b) As a function of the time of day (UTC). Hourly-average indicated by red line. Linear fit vs. forecast hour in (a) indicated by blue line.

b. Comparison with upper-air observations

Observed soundings from the Salt Lake City International Airport showed that a series of inversions and stable layers extended from the surface to near or above crest level (near 700 mb) throughout the event (Fig. 2-6). All morning soundings (1200 UTC) featured strong near-surface inversions that were surmounted by a series of inversions or stable layers (Figs 2-6a,c,e,g,i). During the day, convective boundary layer (CBL) growth was extremely limited. On several days, there was little evidence of an afternoon CBL in the observed data (e.g., Figs. 2-6b,f,j), while on others a shallow CBL was found but extended to a vertical mixing by convection was extremely limited near the ground and above the surface layer.

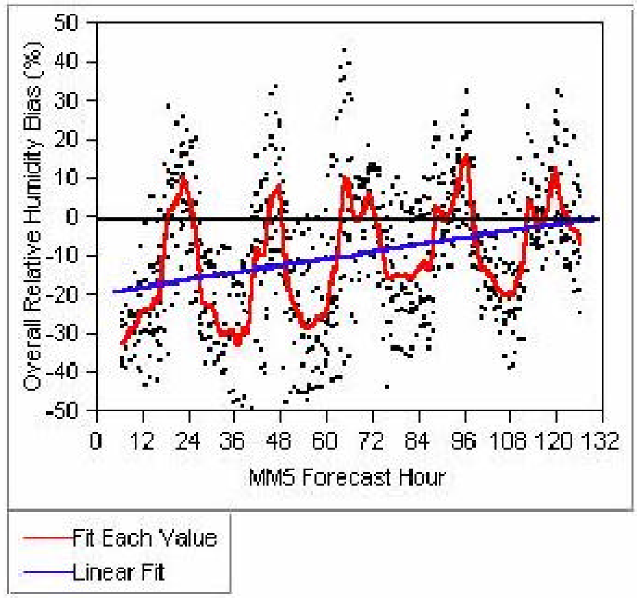
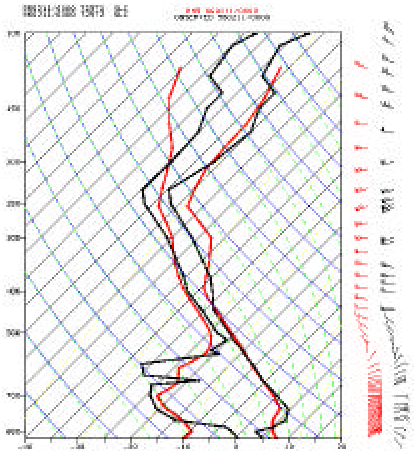
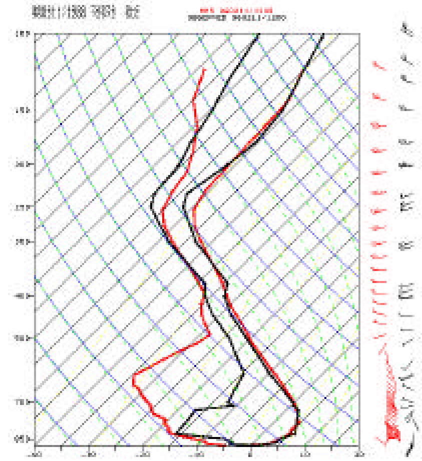


Figure 2-5. Relative humidity bias error scattergram
Hourly-average indicated by red line. Linear fit vs. forecast hour indicated by blue line.

As illustrated by **Fig. 2-6**, the MM5 simulation captured the general thermodynamic structure of this event with one notable exception. The model did not appear to develop the shallow CBL that was observed on some afternoons (**e.g., Figs. 2-6d,h**). Instead, lapse rates remained stable as the near-surface layer warmed. It is possible that vertical diffusion or parameterized mechanical mixing prevented the model from realistically simulating the shallow CBL. Pronounced lower to middle tropospheric dew point contrasts were also evident, but at these temperatures represent small absolute errors in mixing ratio.



(a)



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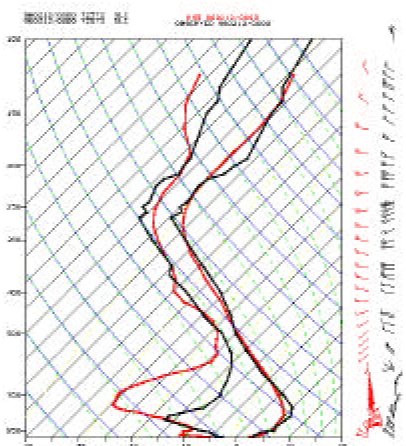

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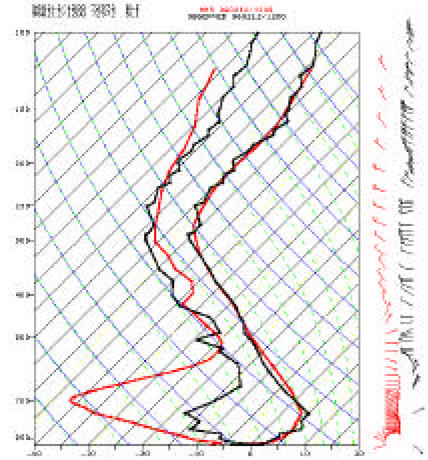

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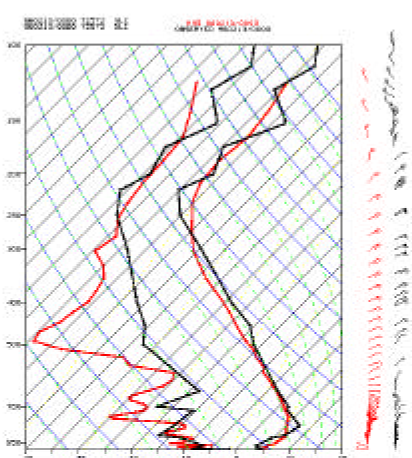

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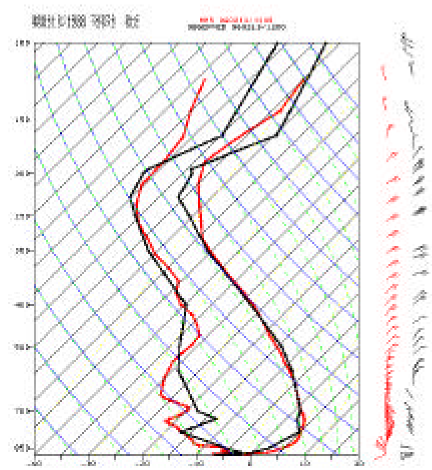

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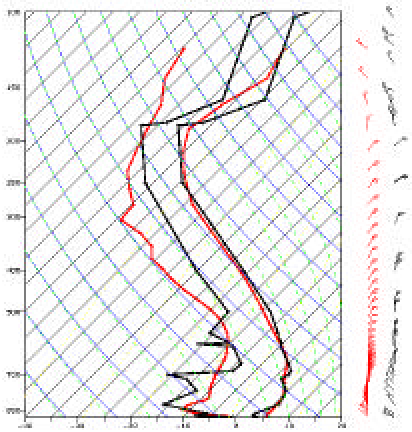

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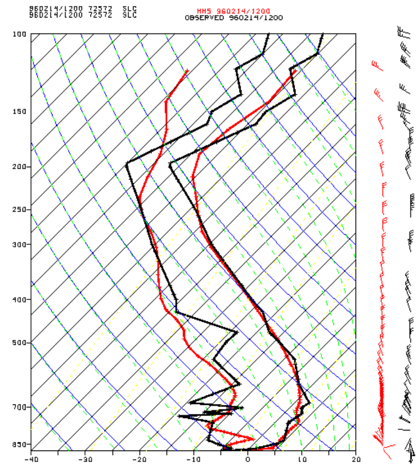

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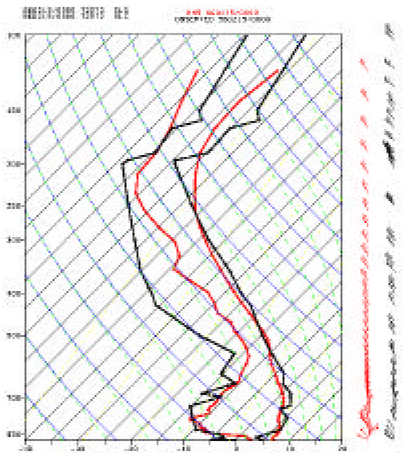
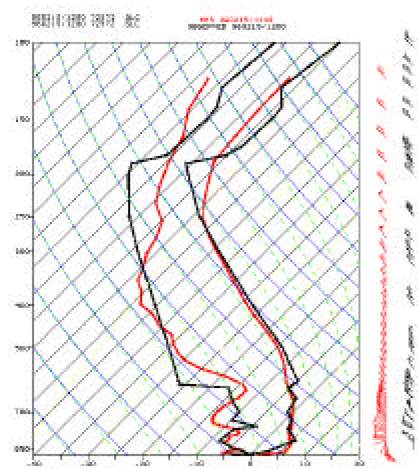


(i)

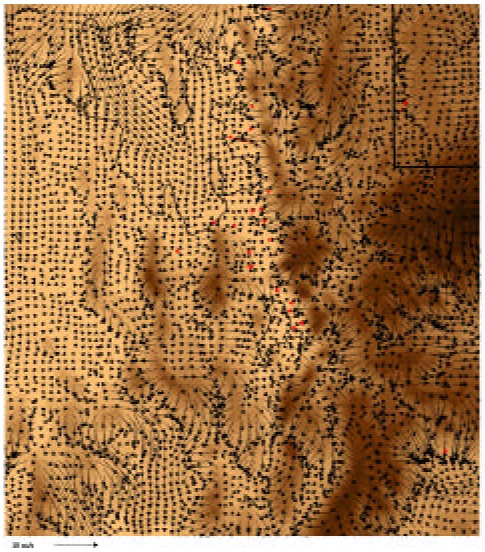


(j)

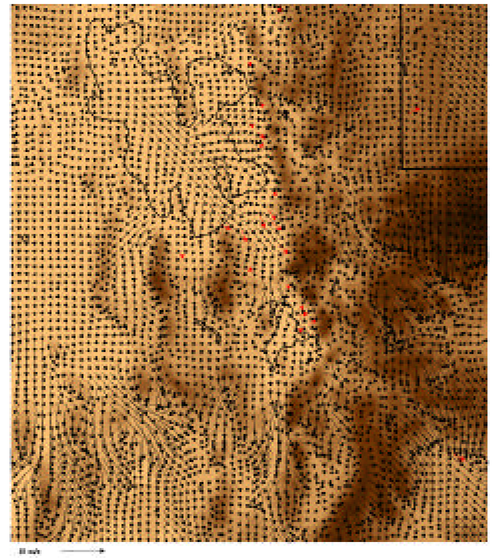
Figure 2-6. Observed (black) and simulated (red) SkewT-logp diagrams
(a) 12 UTC 11 Feb, (b) 00 UTC 12 Feb, (c) 12 UTC 12 Feb, (d) 00 UTC 13 Feb, (e) 12 UTC 13 Feb, (f) 00 UTC 14 Feb, (g) 12 UTC 14 Feb, (h) 00 UTC 15 Feb, (i) 12 UTC 15 Feb, and (j) 00 UTC 16 Feb. Full and half barb denote 5 and 2.5 m s-1, respectively.

c. Comparison with surface observations

To illustrate and evaluate the nighttime and daytime circulations produced by the MM5, simulated and observed winds were vectorially averaged, with the mean circulations at 1200 and 2100 UTC presented in **Fig. 2-7**. At 1200 UTC, simulated flows over populated regions removed from the sloping terrain of the Wasatch and Oquirrh Mountains were very light (< 1.5 m s-1), in agreement with observations. Stronger simulated winds were produced along the sloping terrain of the Wasatch Mountains and other ranges, but observations were not available in these locations to validate the intensity of such flows. The magnitude of the simulated downslope flow at the University of Utah appeared to be stronger than observed. At Hill Field, where localized outflow from Weber Canyon occurs, simulated winds were weaker than observed.



(a)



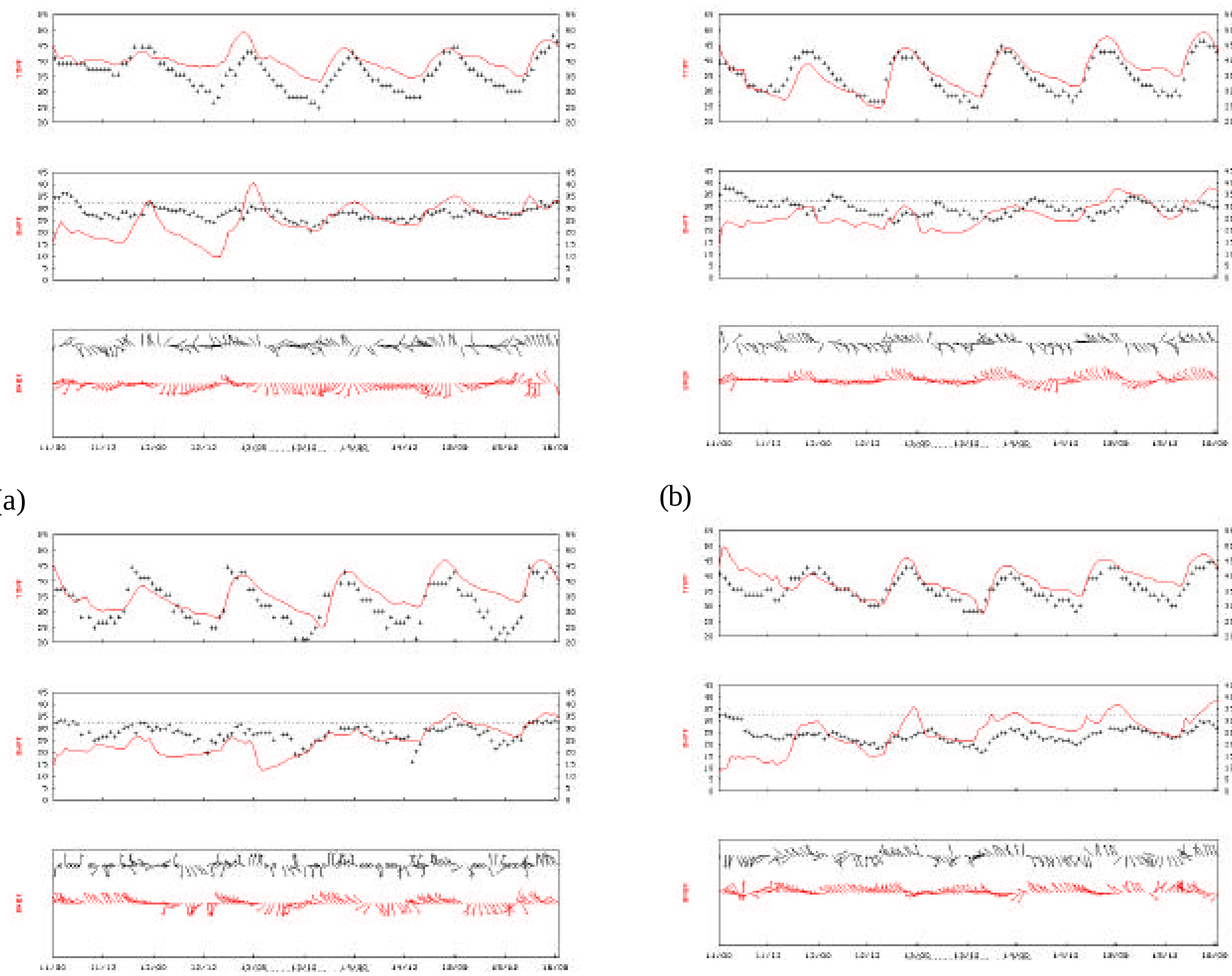
(b)

Figure 2-7. Simulated (black) and observed (red) vector-averaged winds
(a) 1200 UTC and (b) 2100 UTC. Vector length based on scale at top.

During the afternoon (2100 UTC), diffluent northwesterly flow was produced by the model over the Salt Lake Valley, the result of up-valley and upslope flows. Some enhancement of this circulation appeared to result from onshore flow produced by the Great Salt Lake. This simulated flow verified well at many locations. Exceptions include Cottonwood Heights (QCW), where the direction was accurate, but the simulated flow was weaker than observed, and Salt Lake City International Airport (SLC), where the simulated flow had a more westerly component and was weaker than observed. Over Utah Valley, both the simulated and observed winds were light. The simulated flow appeared to have more of a northerly component than the observed flow, which at many sites was westerly or west-southwesterly. Over the northern Wasatch Front, simulated and observed winds were light with some differences in wind direction.

Figure 2-8 compares the simulated and observed winds at four selected locations: Lindon (QLN, 1451 m), which is located in Washington County, Cottonwood Heights (QCW, 1328 m), which is located on the east bench of the Salt Lake Valley, Salt Lake City International Airport (SLC, 1288 m), which is located along the base of the Salt Lake Valley, and Washington Terrace (QWT, 1347 m), which is located in the northern Wasatch Front near Ogden. As illustrated by Table 2, the largest departures from observations occurred over Utah County, and this is apparent in the QLN time series (**Fig. 2-8a**). Simulated temperatures were generally higher than observed, particularly at night. Moisture errors were pronounced during the first 2 days of the simulation, but then became relatively small. Observed winds were very light (2.5 m s-1 or less), and showed little organization, although there was some tendency for northerly or northwesterly flow during the afternoon (1800-0000 UTC). The simulation produced such a flow only for a brief period during two afternoons (the 12th and 15th), and occasionally produced winds that were stronger than observed.

The simulation over the Salt Lake Valley was more accurate. At QCW, the simulated temperature was generally within 2.5°F of observed, with the largest errors at night (**Fig. 2-8b**). Some under prediction of temperature was evident early in the event, whereas an over prediction was apparent later in the event. Although the simulated mean dewpoint was near or just below observed, the simulated and observed diurnal dewpoint fluctuations did not appear to be phased. Observed winds at QCW at a given time showed strong consistency from day to day. At night and during the early morning (~0400-1600 UTC), winds were light and from the south-southeast. During the afternoon and early evening (~1700-0300 UTC), light northwesterly flow was observed. The MM5 simulation also showed strong consistency from day to day. The simulated nocturnal flow was light, but westerly or southwesterly. The simulated afternoon flow was northwesterly, but stronger in magnitude than observed. Thus, at all times, the upslope component of the flow at this location was stronger than observed.



(a) (b)

(c) (d)

Figure 2-8. Observed (black) and simulated (red) time series of temperature (°F), dewpoint (°F) and wind

(a) Lindon (QLN), (b) Cottonwood (QCW), (c) Salt Lake City Intl. Airport (SLC), and (d) Washington Terrace (QWT) (full and half barb represent 5 and 2.5 m s-1, respectively)

At SLC, a warming trend was evident in the simulated temperature time series, whereas day to day temperatures remained relatively steady in the observations (**Fig. 2-8c**). The diurnal temperature cycle was also under-predicted. Simulated dewpoints were too low during the first 2.5 days of the simulation but are close to observed for the remainder of the simulation. Simulated winds exhibited a pronounced diurnal cycle with northwesterly flow in the afternoon and southerly to southeasterly flow in the evening and at night. A similar, but less pronounced, diurnal cycle was evident in the observations. The observed afternoon flow also tended to be northerly, whereas the simulated flow was northwesterly.

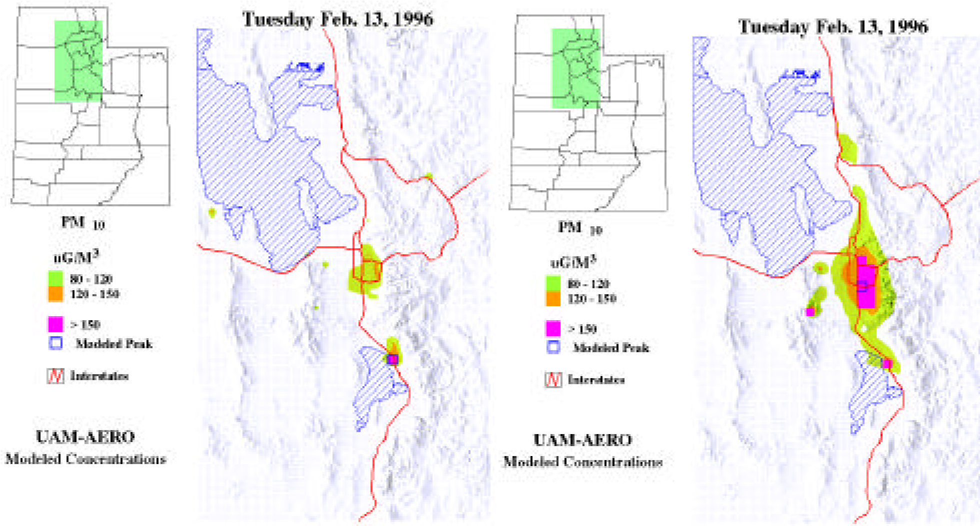
Simulated temperatures at QWT were generally within 2.5°F of observed, except during the first 12-h of the simulation (**Fig. 2-8d**). A weak warm bias was also evident during the latter half of the simulation when simulated temperatures were generally warmer than observed. Other than the first 12 h of the simulation when a dry bias was evident, simulated dewpoints were generally near or above observed. Observed surface winds at this station were very light, with some tendency for afternoon northwesterly-northerly flow and southerly nighttime flow. This local diurnal wind cycle was not evident in the simulation, which produced northwesterly flow most nights that became westerly in the late afternoon.

2.4 Input to UAM-AERO

The UAM-AERO was configured with 4-km grid spacing, 33 grid points in the zonal direction, and 56 grid points in the meridional direction. Five vertical levels were positioned such that 2 (3) levels were located below (above) a diffusion break. The height of the diffusion break was allowed to vary spatially and temporally between 80 and 1400 m AGL. Meteorological inputs to UAM-AERO included wind, temperature, moisture (mixing ratio in parts per million), and fog/haze. Wind, temperature, and moisture are 3-dimensional fields (i.e. 5 levels) and fog/haze was a 2-dimensional field consisting of a fog index of 1, 2, or 3 (1=clear, 2=hazy, 3=foggy).

Meteorological input for the UAM-AERO was generated in the following manner. First, a Diagnostic Wind Model (DWM) was used to provide wind fields at levels below a diffusion break created using the Atmospheric Boundary Layer Model (ABLM, see Appendix for details). The DWM and ABLM were used because initial testing of the UAM-AERO using low-level MM5 winds and an MM5-derived diffusion break resulted in lower than observed PM_{10} levels over the Wasatch Front due to excessive eastward pollutant transport across the Wasatch Crest (cf. **Fig. 2-9a**). More accurate concentrations were produced by the simulation using DWM winds and the ABLM diffusion break (**Fig. 2-9b**). Temperature and moisture input for UAM-AERO, as well as wind input at levels above the diffusion break, were generated by interpolating the MM5 forecast horizontally to the UAM-AERO grid using an overlapping parabolic interpolation technique (Manning and Haagenson 1992). Over low-elevation regions (i.e., MM5 elevations = 1400 m) lowest-level temperature and moisture inputs were also bias corrected based on hourly domain-averaged bias errors. This corrected for the inability of the MM5 to fully resolve the near-surface temperature inversion and the tendency for the surface layer to be too dry during the first part of the simulation. Because of limited observational data at higher elevations, bias corrections were not applied above 1700 m, while at intermediate elevations (1400-1700 m), a linear transition was specified.

The fog/haze field was derived in the following way. Since most stations do not report fog or haze, but do report relative humidity, observations from SLC were used to derive a relationship between relative humidity and observed fog and haze. It was found that during 11-16 Feb 1996, haze was usually reported at SLC when the relative humidity was 60-90%, and fog was reported if the relative humidity was greater than 90%. These thresholds were used to specify fog at all low-level (i.e., MM5 elevation = 1500 m) grid-points within 25 km of a station reporting relative humidity, with the observed relative humidity used to specify fog or haze. If no observations were available within 25 km of the UAM-AERO grid point, fog was specified based on the MM5 simulation and SLC observation using a lookup table (Table 3). Above 1500 m, fog was prescribed only if the MM5 predicted explicit cloud water or if relative humidity exceeded 97.5%. This approach allowed the fog/haze field to resemble the SLC visual fog/haze observation temporally, but resemble the MM5 relative humidity field spatially.



(a) (b)

Figure 2-9. Daily-averaged PM_{10} concentrations for 13 February 1996
(a) UAM-AERO simulation using exclusively MM5 input. (b) UAM-AERO simulation using DWM winds, ABLM diffbreak, but otherwise MM5 input (see Appendix for details).

2.5 Summary

This paper has presented a statistical and subjective evaluation of the mesoscale model simulation used to provide meteorological inputs for grid-based aerosol modeling of the 11-16 February 1996 PM_{10} event over northern Utah. The model (MM5) was configured with a horizontal grid spacing of 2-km to help resolve local orographic effects, and utilized data assimilation to limit model error growth. The simulation captured the general character of the event, producing a series of inversions and stable layers that extended from valley to crest level, and diurnal wind system reversals. More detailed analysis revealed a nocturnal warm bias in valley locations, that was due in part to the inability of the model to fully resolve the nocturnal inversion, an underdevelopment of the shallow convective boundary layer (< 250 m) that was observed on some afternoons, a low-level dry bias that gradually became negligible during the simulation, and diurnal oscillations in surface temperature and moisture bias errors.

Table 2-3. Fog/haze lookup table for UAM-AERO grid points with no nearby relative humidity observation.

MM5 RH / SLC Observation	< 60%	60-70%	70-80%	80-90%	90-100%
clear	clear	clear	clear	haze	fog
haze	clear	clear	haze	fog	fog
fog	clear	haze	fog	fog	fog

Output from the MM5 was used to generate most meteorological input for the grid-based aerosol model (UAM-AERO), with the exception of wind fields below the diffusion break and fog/haze fields. The former was generated with a diagnostic wind field because wind produced by MM5 resulted in excessive transport of pollutants across the Wasatch Crest. The cause of this transport is unknown. Because of the difficulties in simulating fog and haze evolution in current mesoscale models, the former was prescribed using both observed and modeled relative humidities based on the observed 0relationship between fog/haze and relative humidity at the Salt Lake City International Airport during the event.

The results suggest the need for additional research to improve our understanding, analysis, and simulation of vertical transport and mixing during inversion periods along the Wasatch Front. Of particular concern are transport and mixing processes along the steeply sloped Wasatch Mountains, where UAM-AERO simulations using winds from both MM5 and a diagnostic wind model showed more cross-barrier pollutant transport than is believed to occur based on the visual characteristics of wintertime air quality events. Future research should also aim to better represent horizontal transport, vertical transport, and mixing within intense inversions and stable layers in both meteorological and air chemistry models.

2.6 Background Information

2.6.1 Meteorological Inputs

Sonoma Technology, Inc. (STI) prepared the final wind and diffusion break files used as input to UAM-AERO. This section, prepared by Neil Wheeler of Sonoma Technology, Inc. describes the methodologies used in preparing those files.

2.6.2 Winds

The University of Utah developed initial UAM-ready wind fields based on MM5 simulations for the episode. Because of difficulties representing wind flow in the shallow stable layers present in the Salt Lake and Utah valleys during this episode with MM5, a hybrid prognostic-diagnostic wind modeling approach was utilized. The Diagnostic Wind Model (DWM, Douglas et al. 1990) was used to create second guess wind fields using surface wind observations from surface-based air quality monitoring sites, winds aloft from two SODARs, and winds aloft from six soundings extracted from the UAM-ready winds based on MM5 (Table 2-4). Surface sites were selected based on exposure characteristics and recommendation reported in a UDAQ site audit report.

Table 2-4. Sites used to develop DWM wind fields.

Type	ID	UTM-E (Km)	UTM-N (Km)
Surface	GEN	437.5	4460.7
Surface	NOR	440.1	4462.6
Surface	QCW	428.1	4499.1
Surface	QGV	375.6	4495.4
Surface	QHE	413.6	4486
Surface	QHG	432.1	4475.8
Surface	QLN	439.7	4465.7
Surface	QWO	438.8	4461.3
Surface	QWT	417.8	4559.2
Surface	QB4	397.8	4509.8
Surface	QMG	407.6	4506.6
SODAR-UA	AMC	424.2	4512.1
SODAR-UA	GEN	437.5	4460.7
MM5-UA	MM5-1	418.2	4514.8

MM5-UA	MM5-2	416	4564
MM5-UA	MM5-3	440	4452
MM5-UA	MM5-4	376	4500
MM5-UA	MM5-5	376	4548
MM5-UA	MM5-6	368	4432

The DWM has an option to minimize vertical velocities at the top of the modeling domain. However, for this application the minimization routine was modified to minimize vertical velocities at the diffusion break. This was necessary because shallow stable layers were frequently evident in the valleys and interpolation induced divergence resulted in unrealistic vertical velocities at the top of the diffusion break that vented pollutants from the valley to layers aloft.

The DWM winds for the surface were used to estimate the diffusion break as described in the following section. Based on the revised diffusion break estimates, both the MM5 and DWM winds were mapped into UAM vertical layers that are relative to the diffusion break. Finally, the MM5 and DWM wind fields were merged with the DWM being used for layers below the diffusion break and MM5 being used above the diffusion break.

2.6.3 Diffusion Break

The diffusion break files were created using the Atmospheric Boundary Layer Model (ABLM) version 1.09. ABLM is based on mechanical mixing models suggested by van Ulden and Holtslag (1985) for stable and neutral conditions and a convective zero-order thermodynamic jump model, which includes the effects of subsidence and advection, proposed by Steyn and Oke (1982). Friction velocity and Monin-Obukhov length are calculated as in MPDA (Paumier et al. 1986). The Holtslag and van Ulden (1983) scheme is used to estimate surface heat fluxes. Sensible and latent heat are partitioned using a modified Priestly-Taylor method. A routine to calculate advective fetch, either by backward trajectory or straight line fetch, was developed for use with the Steyn-Oke model. These submodels have been placed in a framework suitable for generating gridded mixing depths for input to photochemical grid models. ABLM requires the following gridded meteorological and geophysical inputs:

? Surface Temperature (degrees Kelvin)
? Surface Wind - East Component (meters per second)
? Surface Wind - North Component (meters per second)
? Surface (Station) Pressure (millibars)
? Cloud Cover (tenths)
? Inversion Base Height (meters above ground level)
? Inversion Intensity (degrees Kelvin per meter)
? Mean Mix Layer Potential Temperature (degrees Kelvin)
? Surface Roughness Length (meters) – this may be gridded or by category
? Land Use Category (non-dimensional) – user defined

Surface temperatures were taken from the UAM-ready temperature files prepared from MM5 output. Surface winds were from the DWM as described above. Surface pressure was assumed to be constant at 873 mb. No cloud cover was assumed except when fog was identified as present in the UAM-ready fog files. The inversion base height was arbitrarily set to 300 m. The inversion base height is used to limit the mechanical mixing depth in the neutral case and is non-critical. Specifying a maximum mechanical mixing depth (as done in this application) overrides the use of the inversion base as a limit. The inversion is not used if it is surface based.

Daily mean inversion intensities and mean mixed layer temperatures were estimated from available sounding and are summarized in Table 2-5. Land use categories and associated surface roughness length were the same as those used as input to UAM-AERO.

Table 2-5. Inversion intensity and mixed-layer temperature input to ABL

Date	Inversion intensity (K/m)	Mean mixed-layer potential temperature (K)
11 Feb 1996	0.013	283.0
12 Feb 1996	0.016	285.0
13 Feb 1996	0.02	283.0
14 Feb 1996	0.02	284.0
15 Feb 1996	0.02	285.0

2.7 References

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3.0 The SMOKE Emissions Model and Processor

The emissions processing model used in conjunction with UAM-AERO is the Sparse Matrix Operator Kernel Emissions Modeling System (SMOKE). The emissions processing model takes the annual, county-wide emissions inventory prepared by DAQ and reformulates it for use in the air quality model. There are three aspects to this reformulation of the inventory which, in the end, produces a refined version of the inventory.

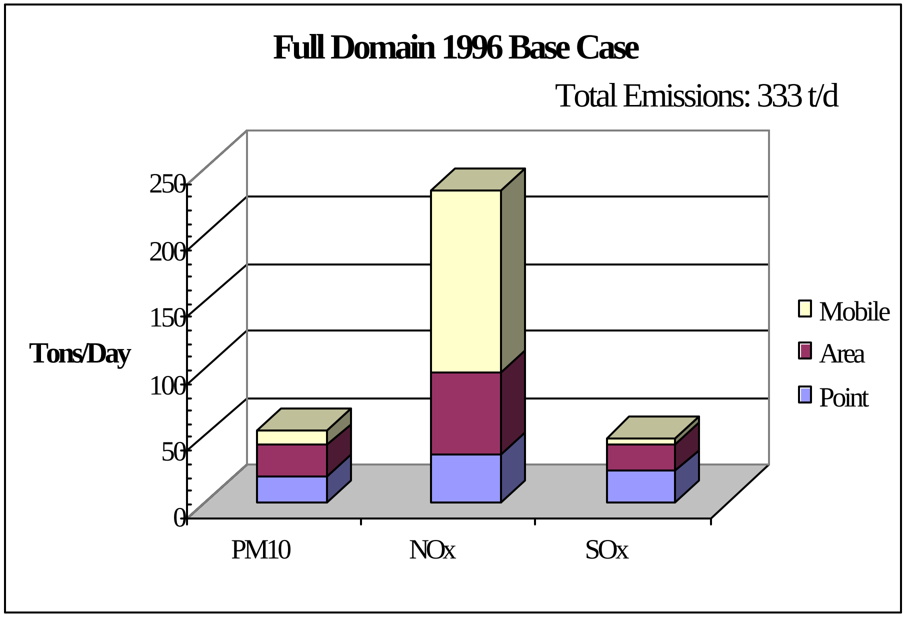
1) Temporal processing: Convert emissions from annual to daily and hourly values.
2) Spatial processing: Convert emissions from a county-wide average to emissions in a 4 square kilometer grid cell.
3) Speciation: Break PM_{10} and VOC emissions into their component subspecies.

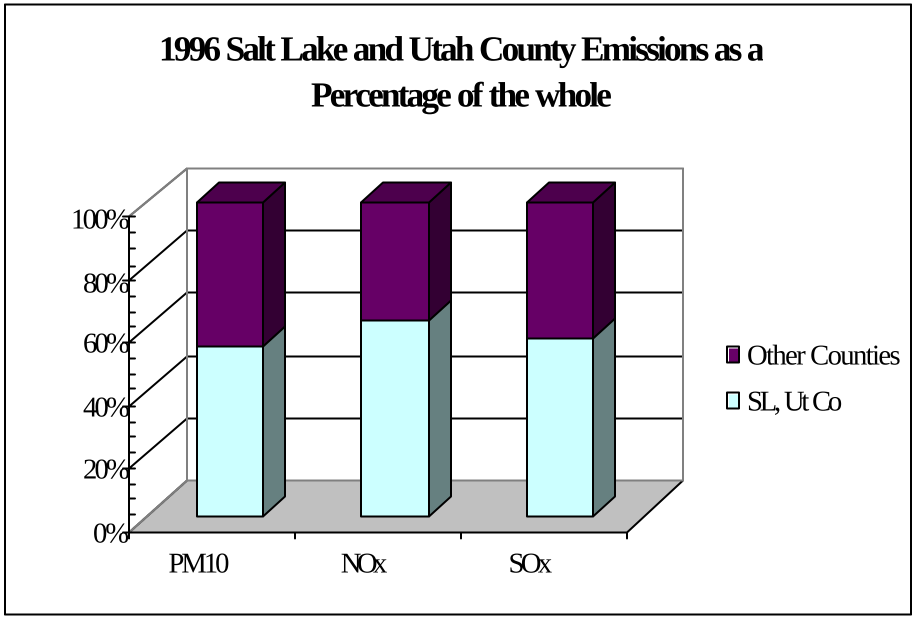
The emissions processing for air quality modeling is done with sets of activity profiles and associated cross reference files. These are created for point or large industrial source emissions, area sources that are small but spread out over large areas such as dry cleaning establishments, and mobile sources such as automobile and truck traffic. The existing inventories of primary PM_{10} and PM_{10} precursors are modified to reflect winter conditions of 1996, augmented with an ammonia emission inventory, and reviewed thoroughly for accuracy and completeness. The 1999 annual inventory will be used to create the future year projection inventories. The 1999 inventory is used for projections rather than the 1996 inventory because the collection procedures and emission factors are the most complete and up to date accounting that is available.

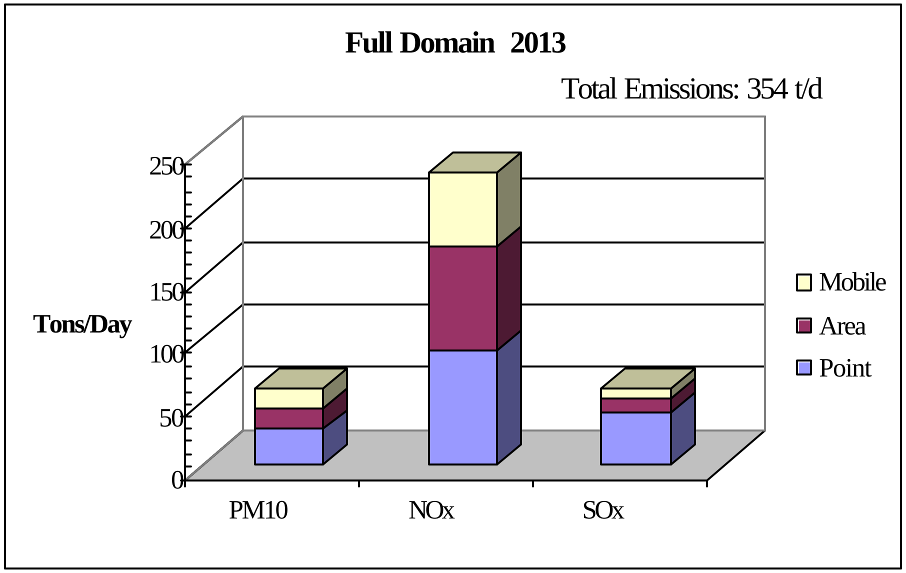
The emissions from large industrial sources are placed in the location of the source itself. For area and mobile source emissions spatial surrogates are created. For example, the emissions from wood stoves for home heating are placed in the model using population density as the surrogate. Using this approach no wood stove emissions for home heating will be put into the model in areas of the domain that are unpopulated. Emissions from automobiles are distributed using traffic estimates provided by the Metropolitan Planning Organizations.

Splitting the PM_{10} and VOC emissions into subspecies is done to allow the air quality model to process the chemical reactions in the atmosphere. Since the reaction of these subspecies in the air accounts for a significant part of the total PM_{10} concentrations along the Wasatch Front it is important to account for them. A set of chemical profiles and cross reference files is created for the sources of these emissions and used for this processing. Once the emissions are speciated, the individual species serve as input to the air quality model.

Once cross reference tables are created to define the relationships between the annual emissions inventory and the temporal, spatial, and chemical aspects of the data, the SMOKE emissions model is run. Figure 3-1 shows the daily emissions inventory of SO_x, NO_x, and PM_{10} for the entire modeling domain for 1996 and 2013. It also shows the combined Salt Lake and Utah County inventories as a proportion of the entire modeling inventory for these two periods.







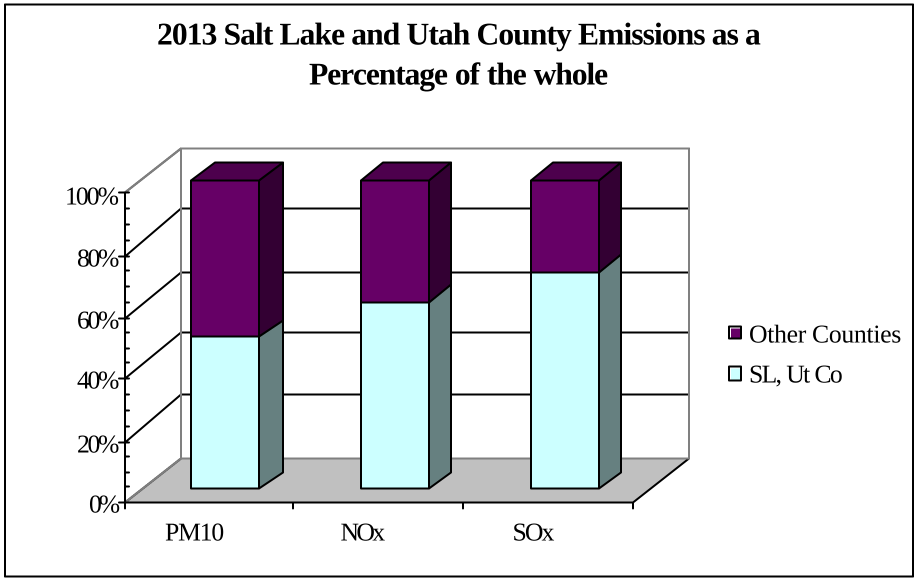


Figure 3-1. Inventory Comparisons

3.1 Temporal Processing

The goal of temporal processing is to provide more detail about the emissions inventory during the actual episode being modeled. For example, beginning with annual average data one first decides how the activity is distributed over the year. A larger proportion of emissions from home heating fuels will occur during the winter months as opposed to summer. Next would be the distribution throughout the month. For automobile emissions one might assume that there is a difference between the amount of daily driving done on the weekends and that done during weekdays. Since one of the days during the episode falls on Sunday the amount of mobile source emissions on the weekend and non-weekend days is adjusted accordingly. The final level of temporal refinement seeks to distribute the emissions throughout the day. If a particular industrial process operates seven days a week but only at night, those emissions will be fed to the model only during those hours of operation.

Temporal profiles for on-road mobile sources are developed based on vehicle-miles-of-travel (VMT) data obtained from UDAQ. Temporal profiles are developed for urban and rural interstates for weekdays and weekends based on hourly VMT data. Figures 3-2 and 3-3 show the VMT data used to develop temporal profiles to distribute on-road mobile source emissions for weekdays and weekends.

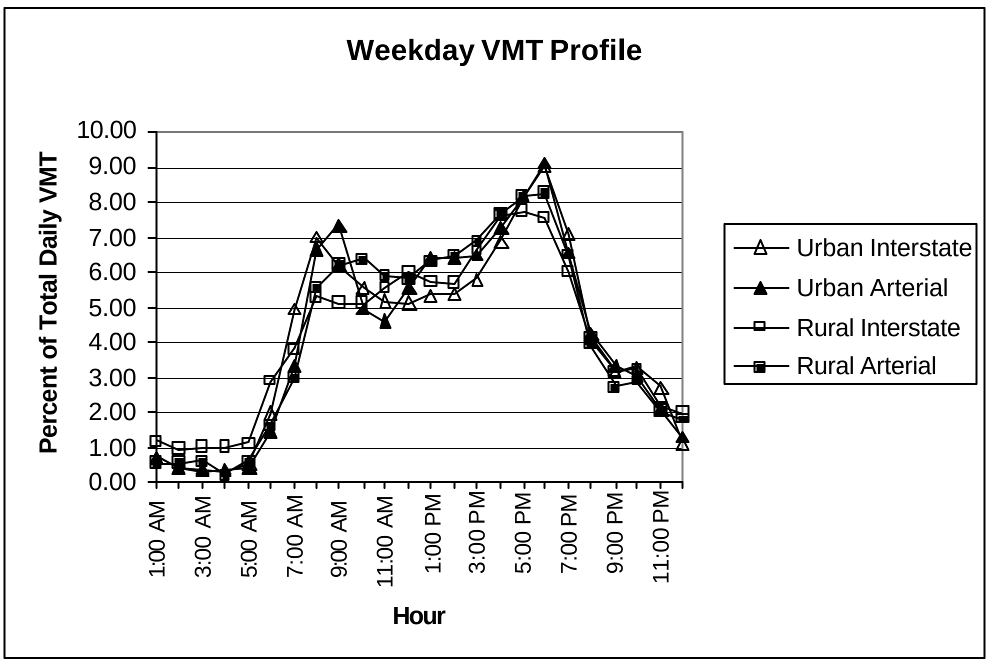


Figure 3-2. Weekday temporal VMT distributions used to develop temporal profiles for distributing on-road mobile source emissions (Monday through Friday).

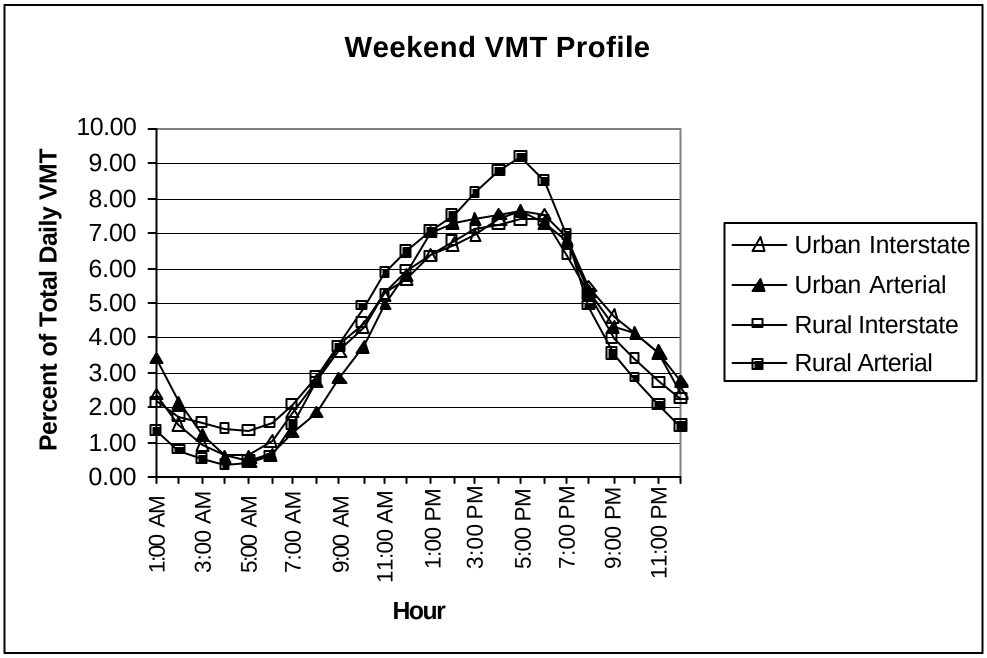


Figure 3-3. Weekend temporal VMT distributions used to develop temporal profiles for distributing on-road mobile source emissions (Saturday and Sunday).

Development of area source temporal profiles began with investigating the EPA-recommended diurnal and weekly profiles assigned by SCC and the monthly profiles contained in the CARB emission inventory system. The EPA-assigned profiles were adjusted to reflect actual conditions of different source categories within the Utah modeling domain. Several new diurnal profiles were created for specific source categories, the temporal profiles for which were not represented in the CARB temporal profile library. Chapter 3 Appendix B contains the temporal profile assignments for all area source categories, including notes justifying the selection of each profile.

Temporal profiles were developed for individual point sources within the modeling domain that emitted 50 tons or more of PM_{10}, SO_2, NO_x, or VOC in calendar year 1996. All recommended temporal profiles were based on information supplied by affected companies in 1996. The quarterly activity assigned to each point source is the actual percentage of annual activity reported by the facility for January 1 through March 31, 1996. It was necessary to create one new weekly profile and four new diurnal profiles to address the point source profiles.

The Source Classification Code (SCC) assigned to open burning was used for both Alliant Techsystems and Thiokol Corporation; the temporal profiles for each company, however, are different. During selected wintertime episodes, Alliant Techsystems actually conducted open burning on February 12, 1996, and Thiokol Corporation conducted open burning on February 12, 13, and 15, 1996. Temporal profiles were created to reflect these activities.

3.2 Spatial processing

Before SMOKE can be run to create input for the air quality model, several types of data sets must be created using a geographic information system (GIS). This pre-processing allows the emissions to be distributed spatially to individual grid cells throughout the modeling domain. This section describes the process of creating those inputs for the UAM-AERO air quality model.

Although UAM-AERO is run at a 4x4 kilometer resolution the emissions model is run at twice that resolution using grid cells measuring 2x2 kilometer in the x,y plane. The modeling domain covers portions of 13 counties in northern Utah. The modeling domain is shown in Figure 3-4.

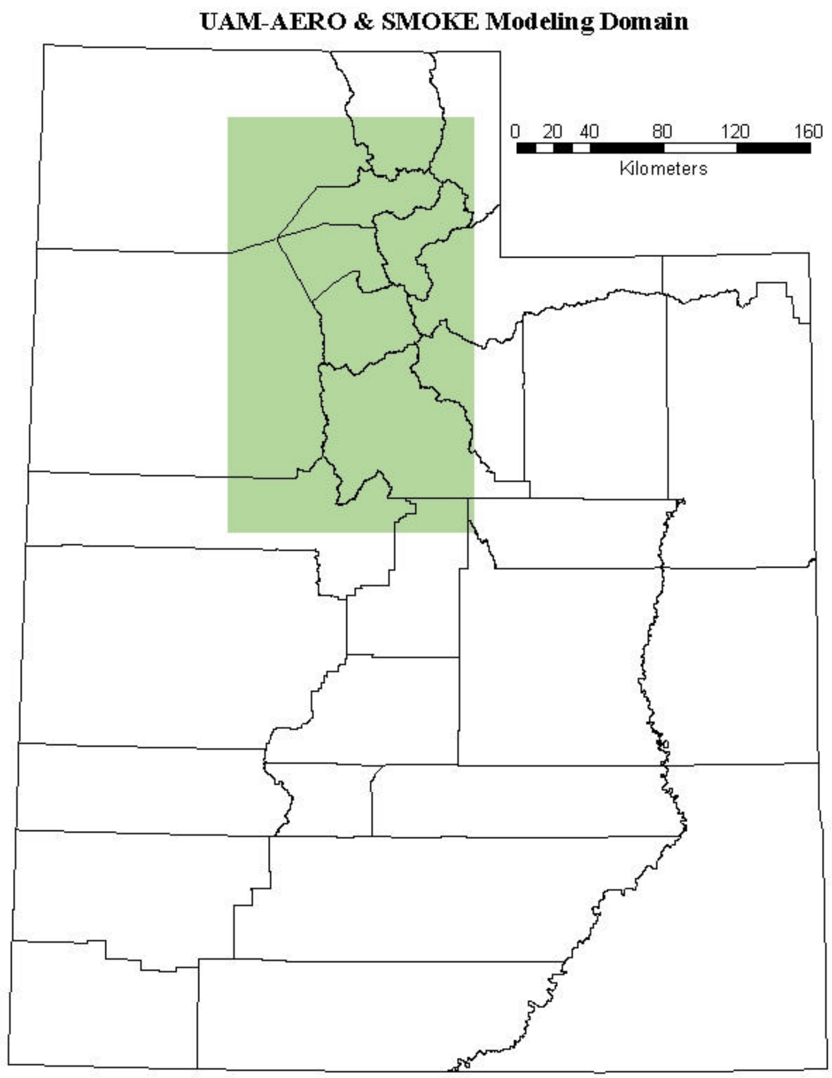


Figure 3-4. Modeling domain 134 x 226 Kilometers

The function of the emissions model in developing the air quality inputs is to allocate a generalized county-wide annual emissions inventory into a much more detailed set of emissions. If day-specific information is available this can also be incorporated into the model. The inventory is processed through the emissions model to allocate the emissions to three different dimensions: spatial, temporal, and chemical speciation. This section describes the development of the files necessary for the spatial allocation of the emissions inventory. These files are created primarily with Arc/Info GIS software creating files in four different categories: land use, population density, and vehicle miles traveled which are used as surrogates for the spatial distribution of certain emissions. The final category is the spatial surrogate file itself.

3.3 Land Use

Land use for the UAM-AERO model is classified into ten categories:

- RANGE
- URBAN
- AGRICULTURE
- DECIDUOUS FOREST
- EVERGREEN FOREST
- MIXED FOREST
- ROCKY GROUND
- WATER
- WETLANDS
- BARREN GROUND

The gridded land use for the domain was developed using two different data sets originally created for different purposes and at different scales. The first data set is a 30 meter resolution grid created in 1997. This land use grid is itself an amalgamation of different data sets, however, its value for this project is its classification of urban, residential, commercial, and agricultural areas in the urbanized area of the domain. The usefulness of this data for the urban area is that the land use classifications come from records of the County assessors office. This is the most current and accurate description of land use in the urban areas that is available.

The remaining land use classifications within the urban area and all of the land use classifications in the rest of the domain were created from the USGS GIRAS data. These are land use and land cover classifications created by the USGS at a scale of 1:250,000. The land use classification based on these two data sets were combined and gridded at both two and four kilometer resolution. Appendix I contains a detailed description of the GIS processing used to create the final land use files. Figure 3-5 is a map of the land use for the modeling domain.

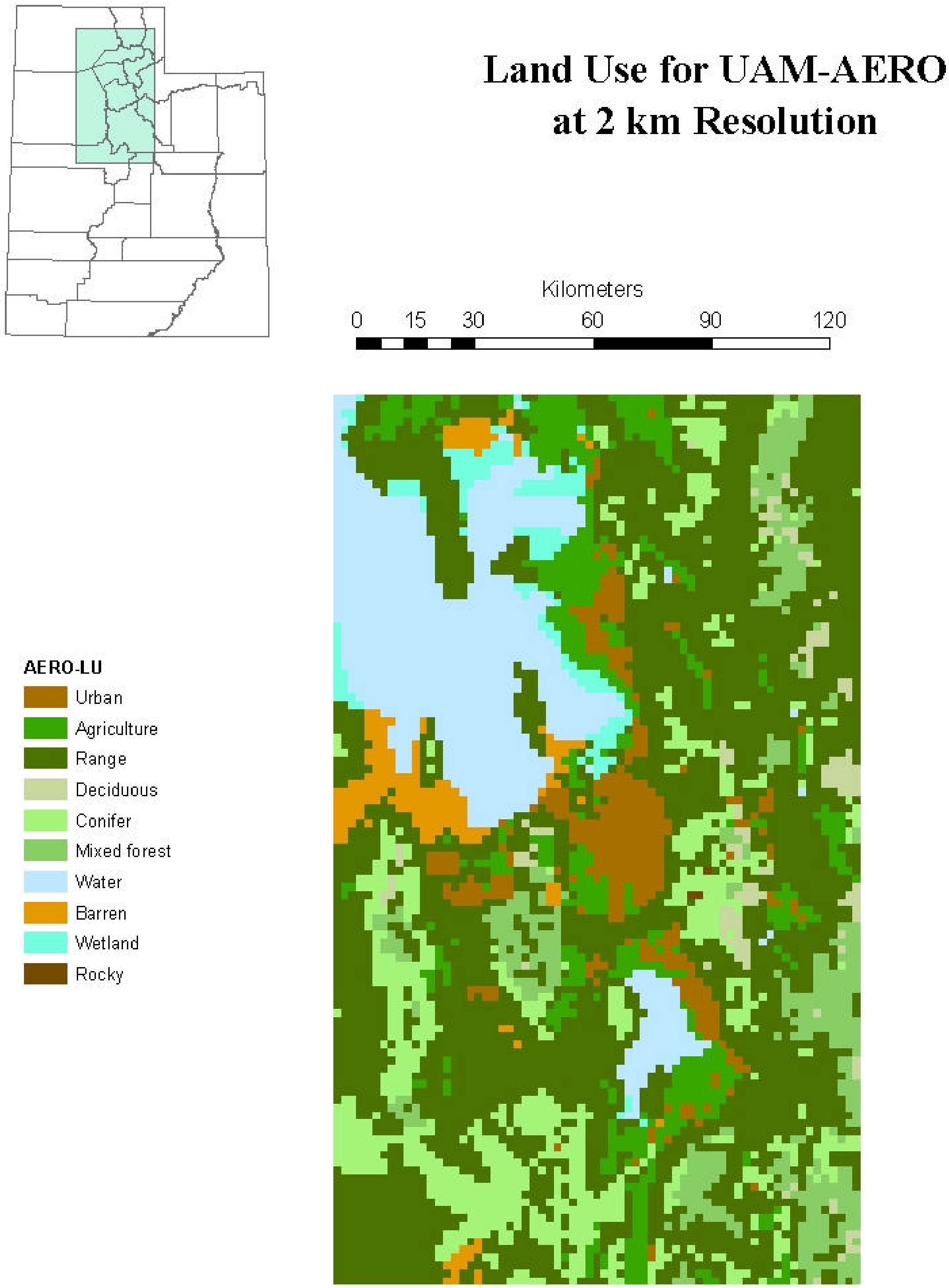


Figure 3-5. Land use in the modeling domain

3.4 Population Density

Population density at a resolution of 2 kilometers for the 1996 base year was developed using three separate data sets. For the four Wasatch Front counties, which contain the urbanized area of the domain, population by traffic analysis zone was provided by the two metropolitan planning organizations (MPO). The Wasatch Front Regional Council (WFRC) provided data for Weber, Davis, and Salt Lake counties. The Mountainlands Association of Governments (MAG) provided data for Utah County. The remaining, outlying, counties in the domain used population estimates provided by the Governor's Office of Planning and Budget (GOPB).

Population by traffic analysis zone is very high resolution data especially in densely populated areas. This data was converted to population density using GIS gridding techniques. The data was first converted to densities at 25 meter resolution to capture the fine scale boundaries of the traffic analysis zones. It was then aggregated to a 2 kilometer resolution to create the population surrogates.

For the outlying counties population was developed from estimates of population within corporate boundaries and the remaining population in the unincorporated areas of the county (http://www.governor.state.ut.us/dea/Profiles/Data/data.html). Using corporate boundaries in the GIS, town populations were placed within those boundaries. Remaining population was assumed to be spread evenly across the rest of the area of the county. Gridded population in the outlying counties was then created in the same manner as that done for the four Wasatch Front counties. Finally, all three data sets were combined into one gridded population data set for the entire modeling domain. Figure 3-6 shows 1996 population in the modeling domain and Chapter 3 Appendix A describes the GIS processing used to develop population density for the domain.

3.5 Mobile Sources

Mobile source emissions data were distributed to the modeling grid using a combination of link-based data and county totals. The data based on county-wide VMT was distributed using population density as a surrogate. As with the population data, the VMT distribution was based on several different data sources. The MPO's provided link based data for VMT on aterial roads and freeways for the four Wasatch counties. UDOT provided link based VMT for state roads and interstates in the outlying counties as well as estimates of VMT driven on local roads.

Where link based data exists the methods outlined in Chapter 3 Appendix A below describe how the VMT were apportioned to each grid cell for freeway and arterial roads. Because link based VMT does not exist for VMT on local roadways the distribution of local VMT was created by using the distribution of the population surrogates. This was done for all counties in the domain. Figure 3-7 shows the distribution of mobile emissions for freeway and arterial roads.

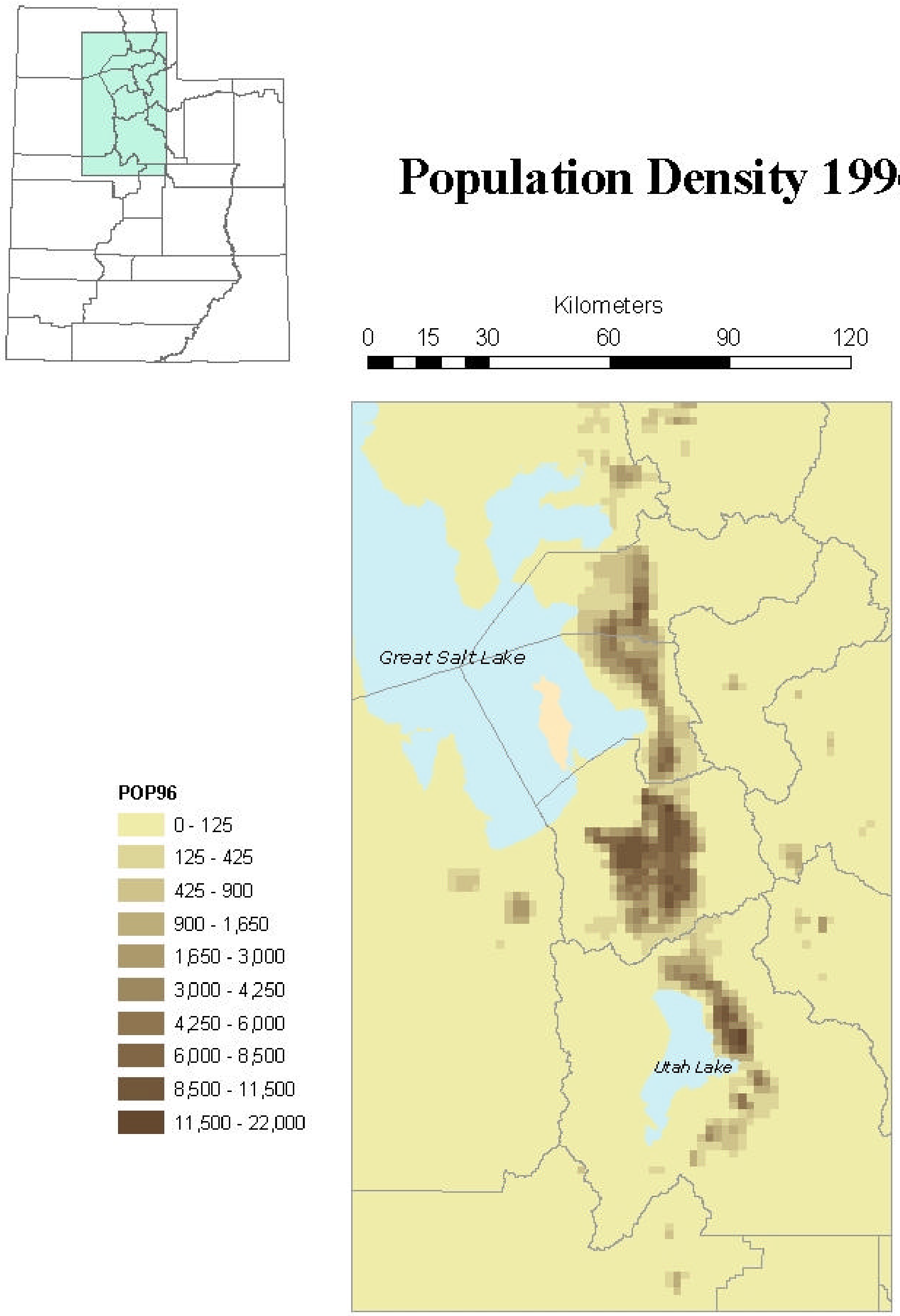


Figure 3-6. 1996 population density in the UAM-AERO modeling domain

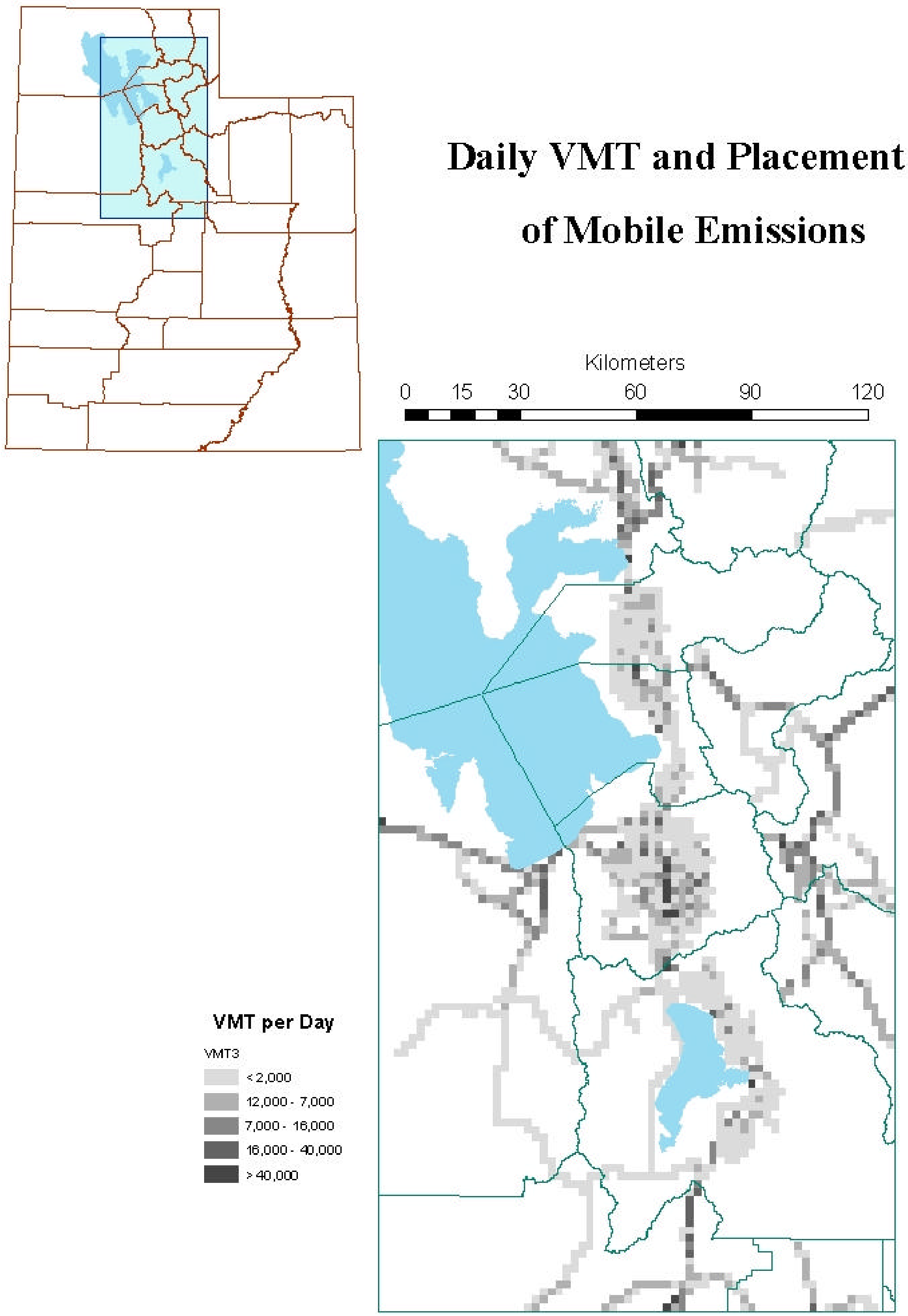


Figure 3-7. Mobile emissions spatially allocated by density of Vehicle Miles Traveled

3.6 Final Emissions Surrogates

The final output from the all of the GIS processing is an ascii file that has the percent of each surrogate in the grid cells within each county. The extraction and recombining of the various GIS coverage into the final data set was done mostly through programming code which is attached in Chapter 3, Appendix A, Section 10.1.

Extensive QA/QC was done throughout all phases of the surrogate creation which is reflected in the appendices. Below is the complete list of surrogates for mobile and area sources that were used when running SMOKE for the 1996 February episode.

SSC	Description
50	Population
51	Housing
55	Urban
60	Area
61	Forest
62	Agriculture
63	Water
71	Airports
72	Highways
74	Railroads
80	POTW
81	Land fills
10	local
20	freeway
30	ramp
40	arterial
41	rural arterial
42	Weber arterial
43	Weber local

The rural arterial is a separate surrogate because of the way vmt is reported by UDOT for the outlying counties. It is both put on a network and additional vmt is reported in the towns and outlying parts of the county.

Extensive documentation detailing the Arc/Info programming used to create the spatial surrogates is provided in the appendices.

3.7 Speciation

Speciation profiles from the U.S. Environmental Protection Agency's (EPA) SPECIATE3 library, the California Air Resources Board (CARB) speciation profile library, and road dust speciation profiles from a report prepared for the Colorado Department of Transportation (Cowherd, 1998) were compiled to develop a library of VOC and PM_{10} profiles for use in emissions processing. The raw VOC and PM_{10} profiles contain many different chemical species. The UAM model accepts VOC input expressed as carbon bond 4 (CBIV) compound groups and the following PM_{10} species and groups: organic matter (OM), elemental carbon (EC), sulfate (SO_4), nitrate (NO_3), ammonium (NH_4), sodium (Na), chloride (Cl), and all other species (OTHER).

The raw VOC speciation profiles were processed so that the individual chemical species in each profile were aggregated into CBIV groups. The PM_{10} profiles were processed so that the individual chemical species in each profile were aggregated into the PM species listed above. The PM species in each profile are reported as mass fractions. In many cases, the raw profiles do not sum to 100%. These profiles are adjusted to sum to 100% by placing mass in the "OTHER" category so that the total mass of PM for each profile is equal to 100%. Many of the PM profiles contain sulfate. In order to avoid double-counting sulfate in the emission inventory, the sulfate mass reported in each profile is changed to zero and the sulfate mass is added to the "OTHER" category to maintain mass balance.

In many cases, the net electronic charge of the PM speciation profiles was not correct. Sodium chloride was used as a surrogate to attempt to correct the charge balance of each PM speciation profile. Because sodium and chloride are fairly abundant in many of the profiles, their masses were used to more accurately estimate the net charge of each profile. The mass values of sodium were adjusted in each profile to electronically balance with the mass of chloride. The EPA default assignments were used to speciate VOC and PM_{10} from point sources.

The EPA default speciation profiles assigned to each area source category were reviewed to determine if the assignment was representative of emissions in Utah. In several cases, the EPA default speciation profile assignments were changed to better represent emissions processes and/or fuel types for Utah. Table 3-1 lists the area source emissions categories, the VOC and PM_{10} speciation profile assignments, and the source of the speciation profile data.

Speciation profile assignments for gasoline exhaust emissions were assigned based on fuel information obtained from Rory MacArthur, Chevron Corporation (2001). Mr. MacArthur reported that the information he provided to STI was obtained from a Southwest Research Institute (SWRI) database containing information about fuel compositions in 1996. The most representative available profiles were assigned to the on-road mobile source categories based on information from the SWRI database. The VOC profiles assigned to the mobile source categories were from EPA's SPECIATE3. Table 3-2 contains a list of the VOC speciation profile assignments for the source categories contained in the emissions inventory that apply to gasoline vehicles.

Several diesel exhaust profiles were obtained and reviewed. The profile assigned to diesel exhaust was taken from the CARB PM speciation library.

Table 3-1. Area source emissions categories and corresponding VOC and PM_{10} speciation profile assignments used to process emissions.

Area Source Category Code	Source Category Description	VOC Profile Code	PM_{10} Profile Code
2501060000	Fuel Distribution (Utah County)	1301 [A]	N/A
2501060000	Fuel Distribution (All other counties)	1305 [A]	N/A
2420000000	Dry Cleaning	1193 [A]	N/A
2460400000	Solvent Cleaning	1195 [A]	N/A
2401990000	Industrial Surface Coatings	1003 [A]	N/A
2401008000	Traffic Markings	2438 [A]	N/A
2460500000	Architechural Surface Coatings	2401 [A]	N/A
2401005000	Autobody Refinishing	1194 [A]	N/A
2425000000	Graphic Arts	1191 [A]	N/A
2461021000	Asphalt Cutback	1007 [A]	N/A
2461800000	Pesticide Application	0076 [A]	N/A
2461000000	Solvent Use	8500 [A]	N/A
50100799	IWT & POTW	2541 [A]	N/A
2620000000	Municiple Landfills	0202 [A]	421 [B]
2501000000	LUST (Utah County)	1301 [A]	N/A
2501000000	LUST (All other counties)	1305 [A]	N/A
2104008000	Woodburning	1167 [A]	42101 [A]
2302050000	Bakeries	9008 [A]	N/A
2104002000	Coalburning	1185 [A]	131 [B]
2104006000	Residential Natural Gas Combustion	0195 [A]	121 [B]
2193006000	Commercial Natural Gas Combustion	1001 [A]	123 [B]
2104005000	Residential Oil Combustion	0001 [A]	42303 [A]
2103005000	Industial & Commercial Oil Combustion	0001 [A]	13504 [A]
2810015000	Forest Fires	0307 [A]	464 [B]
2810030000	Structural Burning	0307 [A]	137 [B]
2801500000	Prescribed, Slash, & Agri Burning	0307 [A]	430 [B]
2810040000	Aircraft Firing & Testing	1099 [A]	141 [B]
2810050000	Vehicle Fires	0307 [A]	462 [B]
2275020000	Aircraft, Landing/Takeoff	1099 [A]	141 [B]
2285002000	Railroads	1201 [A]	425 [B]
2265006000	Misc Non-Road Equipment	1101 [A]	425 [B]
2103006000	Commercial natural gas	1001 [A]	123 [B]
2104004000	Distillate oil	0002 [A]	13504 [A]
2103004000	Commercial distillate oil	0002 [A]	13504 [A]
2610000000	Total all categories - open burning	0307 [A]	461 [B]
2275001000	Military aircraft total	1097 [A]	141 [B]
2270008000	Diesel - airport ground equipment	1201 [A]	425 [B]
2103002000	Commercial bituminous/sub. coal	1185 [A]	131 [B]
2260001020	2-stroke gasoline	1186 [A]	399 [B]
2260004035	2-stroke gasoline	1186 [A]	399 [B]
2265004035	4-stroke gasoline	1186 [A]	399 [B]
2805000000	Livestock Ammonia	N/A	N/A
7000000001	Domestic Animal Ammonia	N/A	N/A
2701460000	Wild Animal Ammonia	N/A	N/A
2701460000	Soil Ammonia	N/A	N/A
7000000002	Human Perspiration, Respiration	N/A	N/A
7000000003	House Cleaning Ammonia	N/A	N/A
31000202	Industrial Point Ammonia	N/A	N/A
50100799	POTW Ammonia	N/A	N/A
2620000000	Municiple Landfill Ammonia	N/A	N/A

[A] Speciation profile source: U.S. EPA SPECIATE3
[B] Speciation profile source: CARB PM speciation profile library

Table 3-2. VOC speciation profile assignments for emissions associated with gasoline vehicles.

Emissions Process (Gasoline Vehicles)	VOC Profile Assignment
Exhaust	1313
Evaporative and Refueling losses	1305
Resting losses	1306
Hot Soak	1307
Running losses	1308

Emissions from tire wear were speciated using the SPECIATE PM profile 34003. A new road dust profile (99995) was prepared to represent conditions in Salt Lake County during the February 1996 episode. The starting point is a profile based on measurements taken in Denver, Colorado, shortly after sanding/salting of the road surface (Cowherd, 1998). The sulfate component (SO_4) was reallocated to the "other" category (OTR). Because the major portion of the episode occurred several days after sanding/salting, it is estimated that 50% of the sand (SiO_2) and 70% of the salt (NaCl) would have been removed from the road surface. The reduction estimates are based on an analysis of speciated measurements of ambient PM_{10} and biases in model performance. The profile was adjusted to account for this removal by reducing OTR by 50% and CL by 70% and then adjusting NA so that the profile is electrically neutral. Finally, the profile was re-normalized so that the sum of all components would equal 100%. These calculations are summarized in Table 3-3.

Table 3-3. Calculation of the revised road dust profile.

Profile	Notes	OM	EC	SO_4	NO_3	NH_4	NA	CL	OTR	Total	Ion Ratio
-	Molecular weights			96	62	18	23	35.5			
D1	Original Denver Fresh Salt/Sand Profile	18.00	2.00	2.33	1.67	0.00	14.33	19.41	42.26	100.00	1.00
99991	Sulfate removed (added to OTR)	18.00	2.00	0.00	1.67	0.00	14.33	19.41	44.59	100.00	1.09
-	Assume after several days that half the sand and 70% of the salt has been removed. Remove 70% NaCl and 50% SiO_2 by reducing CL and OTR, respectively	18.00	2.00	0.00	1.67	0.00	14.33	5.82	22.30	64.12	3.26
-	Adjust NA so the profile is ion balanced	18.00	2.00	0.00	1.67	0.00	4.39	5.82	22.30	54.18	1.00
99995	New profile										
Re-normalized to 100%	33.22	3.69	0.00	3.08	0.00	8.11	10.75	41.15	100.00	1.00	

3.8 Modeling Assumptions

In addition to the steps that are listed above certain adjustments were made to the inventory which reflect reasonable assumptions about some characteristics of the inventory. Changes that were made for the 1996 inventory were carried through for the future year projection inventories as well. The following assumptions were built into the episode-specific emissions inventory for UAM-AERO.

3.8.1 1996 Base Year

The only adjustment made to the area source inventory relates to the credit taken for wood and coal smoke reduction on days which were under red burn conditions. Utah County was under red burn conditions during four of the five days of the episode. Salt Lake and Davis Counties were under red burn conditions for the last two days of the episode, and Weber County had yellow burn conditions on the last day of the episode. The original assumption about wood smoke reduction when mandatory red burn days are called is that 60% of those burning wood comply. It is felt that an 83% reduction in wood smoke is justifiable based on discussions with staff in the EPA Region VIII office.

The estimation of fugitive dust from on-road mobile sources was reduced by 75% from the values generated using the AP-42 emission factors. This reduction was carried through the future year projection inventories and is based on a rule-of-thumb assessment used by EPA in some of its own projects.

Point source emissions were based on the annual inventory with temporal adjustments made as described above. A limited amount of episode-specific data was collected during the 1996 inversion period but was not used in the inventory. The day-specific data was dropped from the inventory after a sensitivity test revealed that there was no change to the modeled concentrations anywhere in the domain when the day-specific data was used or replaced by annual average data. The other changes to the 1996 point source inventory included reducing uncontrolled fugitive dust on company haul roads by 80%. This was done given February conditions with freezing temperatures and snow covered ground.

3.8.2 Future Year Projections

Emissions from wood and coal smoke for future year inventories were not grown at all from 1996 levels. They were held constant throughout all future years and in addition, those emissions from Salt Lake and Davis Counties were assumed to have red burn restrictions four of five days of the episode to match Utah County's restrictions. Both of these assumptions about future year inventory reflect the inputs to the Chemical Mass Balance Model that was being completed in tandem with this study.

For point source emissions, future year inventories contain allowable emission levels for all power plants and gravel mining operations in the entire domain. Allowable emissions for all "large" sources, as defined in the PM_{10} SIP inventory protocol, were input for Utah County. It is expected that when the full maintenance plan for both nonattainment counties is developed, allowable emissions for all "large" sources in Salt Lake County will be included. In addition, all banked emissions in the modeling domain, with the exception of the banked Kennecott SO_2, were used for future year inventories.

4.0 Development of the Base Case Modeling Analysis

Through a series of simulations, analyses, and model improvements we solved many of the problems in the original simulations and eliminated many of the potential causes for the model's under prediction of secondary PM_{10}. Originally it was thought that this under prediction was due to chemistry, however subsequent sensitivity simulations and analyses indicate that this is not the case. The predicted midday decreases in both primary and secondary species over the Salt Lake City urban area suggests that a physical removal process was responsible for the under predictions. This midday loss of species continued to be evident in sensitivity simulations involving deposition, diffusion break heights, and stability.

The general over prediction of primary PM_{10} and the very high concentrations near major stationary sources remain a problem. As expected, sensitivity simulations confirm that predicted primary PM_{10} concentrations are sensitive to wind speed, diffusion break heights, and emissions. We suspect that the over prediction of primary PM_{10} is a result of biases in all three of these inputs to UAM-AERO. Throughout the process of base case modeling efforts were made to evaluate the appropriateness of primary PM_{10} emissions estimates. In particular, these efforts focused on the following areas:

1. Emissions from the silt load on roadways.
2. The rates, speciation, and temporal allocation of emissions from, and the stacks for, major stationary sources in the immediate vicinity of Salt Lake City and Provo.

Because of the low wind speeds and mixing during stagnation episodes like the one being modeled, even small absolute biases can have a significant impact on primary PM_{10} predictions. Because meteorological processes may be affecting both primary and secondary PM_{10} predictions, we did not attempt to remove meteorological biases to address primary PM_{10} performance until the issues with secondary PM_{10} performance were resolved. At that point the following analyses were undertaken:

1. Wind speed biases were re-assessed. The selection of appropriate sites for the bias calculation was based on a review of site locations and exposure.
2. Where significant biases existed, new wind fields were developed by globally applying a factor to remove the average bias.
3. Diffusion breaks heights were re-calculated based on the new wind fields.
4. The affects of the new wind fields were assessed through a sensitivity simulation.

In summary, to achieve an acceptable base case simulation all model improvements were incorporated into a single best simulation.

4.1 Summary of Simulations

A discussion of each simulation is provided below. After each simulation name the meteorology, emissions, and model versions used are shown. For example, "Base Case 1: M1, EB01, V1" means Base Case 1 used version one Meteorology (M1), version one base emissions (EB01), and version one of UAM-AERO (V1).

Base Case 1: M1, EB01, V1

The simulation was the first carried out using episode specific emissions and meteorology. The horizontal grid resolution was 2-km. A preliminary analysis of the diffusion break heights indicated that they were considerably larger than expected and it was discovered that the mechanical mixing depth model for neutral conditions was being used even during stable conditions.

Base Case 2: M2, EB01, V1

This simulation used revised diffusion break heights. To create the new diffusion break file, MM5 output was used to assess stability. The MM5 convective mixing height for unstable conditions and two mechanical mixing depth models for stable and neutral conditions were used. The model results indicated some extremely high concentrations of primary aerosols in the vicinity of certain stationary sources, which led us to review the point source inputs to the model. That review identified problems with the units of various stack parameters. Based on that finding, initial corrections were made to the point source input files.

We found out that PAVE could not be used to visualize the results for some aerosol species because mathematical operators were used in their species names (e.g., NO3-.1) and PAVE tried to interpret the operation.

Base 3: M2, EB02, V2

This simulation used the corrected point source emission files and Version 2 of UAM-AERO, which changed the aerosol species names to exclude mathematical operators so they could be visualized with PAVE. Version 2 of UAM-AERO also included corrections to the solar radiation calculation to eliminate the need to hard-code the Utah domain location in the model.

A review of secondary aerosol concentrations indicated that nitrate aerosol concentrations were an order of magnitude smaller than observed and that nitrate to ammonium ratios (NO3.1/NH4.1) were inconsistent with the model's aerosol chemistry formulation. Results for primary aerosol species indicated problems remaining with point source stack parameters. A thorough review of stack parameters was undertaken and point source inputs to UAM-AERO were revised.

Base 4: M2, EB03, V1

This simulation was run with the latest corrected point source emissions but with Version 1 of UAM-AERO so we were not able to visualize all species with PAVE. Base 4b was run shortly afterwards and this simulation was not thoroughly examined.

Base 4b: M2, EB03, V2

Base 4b was a re-run of Base 4 with UAM-AERO Version 2 and used initial condition (IC) and boundary condition (BC) files that were ion-balanced. The objective of using the ion-balanced IC/BC files was to test whether an initial ion imbalance might be responsible for the inconsistent nitrate to ammonium ratios observed in Base 3.

This simulation improved prediction of primary aerosol concentrations near major point sources but significant over predictions persisted. At this point, several problem areas were evident:

1. Over prediction of primary aerosols near major point sources
2. General over prediction of primary aerosols (i.e., OTR)

3. General under prediction of secondary nitrate aerosols (NO_3) and organic carbon (OC)
4. NO_3/NH_4 ratios inconsistent with model formulation

It is possible that the over prediction of primary aerosol could be due to biases in the meteorology, biases in the emissions, or a result of the 2-km grid resolution. The grid resolution issue would most affect problem 1 as some facilities are so large that they have several grid cells within their fence lines.

It was decided that problem 3 would be investigated first because we could not gain confidence in the secondary aerosol predictions until it was addressed. STI carried out a number of box-model simulations with the UAM-AERO chemistry and debug simulations with UAM-AERO to isolate the problem. It was discovered that the Portland Group compiler used on the Windows NT machines was not initializing a common block in the chemistry routine in the same way as on UNIX platforms and that there was an error in converting concentration units after performing the aerosol chemistry in UAM-AERO. These were corrected in Version 5 of UAM-AERO (Versions 3 and 4 were experimental).

Base 4c: M2, EB03, V5

With the problem with predicted NO3.1/NH4.1 ratios resolved, UAM-AERO Version 5 was used to re-run Base 4. The results of this showed that UAM-AERO was now predicting the expected nitrate to ammonium ratios but problems 1 through 3 remained.

Base 5: M2, EB03, V5b

This simulation was done to assess the impact of grid resolution on the UAM-AERO simulations. All files used in Base 4 were reprocessed at 4-km resolution and Version 5b of UAM-AERO was used. Version 5b is the same as Version 5 but compiled for the 4-km grid instead of the 2-km grid. The simulation showed that the features seen in the 2-km simulation were recreated at 4-km resolution. In general, concentrations of primary aerosol species were spread out more but very high concentrations continued to be predicted around major sources and 24-hr average concentrations of primary aerosols continued to be over predicted at most observation sites.

As in Base 4c, secondary nitrate aerosols were significantly under predicted. We identified improper deposition and/or photolysis rates as possible causes for these under predictions. This led to several additional sensitivity simulations in an effort to define why secondary nitrate concentrations were so low.

Base 5b: M2, EB03, V5c

A review of the UAM-AERO model found that it did not allow use of deposition parameters for the winter season with snow on the ground. The model was modified to allow the use of these parameters and Base 5 was re-run. The simulation showed an increase in the concentrations of several species (including NO3.1) in the rural areas surrounding Salt Lake City and Provo but did little to improve model performance in the urban areas where under prediction of secondary nitrate was a problem.

Base 5c: M2, EB03, V5c

This simulation was used to assess the impact of photolysis rates on secondary aerosol formation. The photolysis rates were recalculated using an albedo of 55% and Base 5b was rerun using these rates. The initial simulation indicated no change in the model predictions. This led us to run the model in debug mode and it was discovered that it was always nighttime in the model. We traced this back to the METSCALARS file, which had a first time interval that covered the entire day. The model was ignoring all following time intervals in the file. Therefore, the model was always using the radiation factor for midnight instead of the correct hour. The METSCALARS file was corrected and this simulation was re-run. A review of the model's mass balance data for this simulation showed that at noon on the last simulation day, there was approximately a two-fold increase in secondary nitrate mass within the entire domain over the original Base 5 simulation. However, nitrate aerosol concentrations within the urban areas remained significantly below those observed.

Base 6: M2, EB03, V6

This simulation was carried out to test Version 6 of UAM-AERO with the option to use deposition parameters for snow conditions being placed in the SIMCONTROL file instead of being hard coded. The simulation was run with new photolysis rates based on an albedo of 45% and was the basis for two additional sensitivity simulations (Base 6b and 6c).

Base 6b: M2, EB03, V6

This sensitivity simulation explored the impact of photolysis rates by doubling the photolysis rates using a scaling factor in the CHEMPARAM file. While the results did show a significant increase in secondary aerosol formation, the concentrations continued to be well below observed values.

Base 6c: M2, EB03, V6

This sensitivity simulation was used to investigate the affect of deposition on model predictions. The simulation used the same doubled photolysis rates as Base 6b but deposition was turned off completely. As expected, there were increases in the concentrations of many species but the prediction of secondary aerosols continued to be below observed values. The combinations of double photolysis rates and zero deposition increased the total mass of NO3.1 in the mixed layer by approximately 50%.

Base 7: M2, EB04, V6

An analysis of primary aerosol concentrations and the diffusion break height near the Geneva Steel facility was performed. The analysis suggested that the over predictions near Geneva Steel could be due to an under prediction of the diffusion break in that region. Calm winds were observed at a nearby site and those winds were assimilated into MM5 leading to an area of calm winds in the UAM-AERO inputs. Because the diffusion break heights are derived from a mechanical mixing depth model for most hours of the day, the low wind speeds influence the diffusion break as well. In reviewing the inputs and model results, it was determined that the Geneva Steel facility was located incorrectly in Utah Lake. Because of the low surface roughness over the lake, the estimates of mechanical mixing are lower than on shore. This simulation replicates Base 6 except the point source emission file was updated to place Geneva Steel onshore.

This simulation was used for a more detailed model performance evaluation and is the basis for the remaining series of sensitivity simulations described below. It should be noted that Base 8 through Base 12 are sensitivity simulations based on Base 7 rather than revised base cases.

In general, we found that nitrate (NO3.1) and organic carbon (OC.1) aerosols were under predicted and other (OTR.1) aerosols were over predicted. Very high concentrations of PM_{10} continue to be predicted near several major sources and near Geneva Steel in particular.

An initial analysis indicated that there might not be enough nitric acid (HNO_3) being formed in the model. HNO_3 is necessary for the formation of nitrate aerosol and during the daytime is formed through the oxidation of NO_2 by the OH radial. However, later comparisons with simulations done for Southern California and findings from the following sensitivity simulations indicate that sufficient HNO_3 may be formed and nitrate aerosol may be produced, but is then being removed.

Base 8: M2, EB04, V6

The purpose of this simulation was to assess the sensitivity of the model to volatile organic compound (VOC) emissions. VOC emissions from ground level sources were doubled, which was expected to increase the availability of OH radicals and enhance HNO_3 and ultimately nitrate aerosol production. While some increases were seen in secondary nitrate aerosol formation, the increases were small. These results imply that either the chemistry is not radical limited and some other mechanism is responsible for the nitrate under prediction or, the chemistry is extremely radical limited and that VOC concentrations need to be increased much more than two times to accelerate the formation of secondary aerosols. Because VOC observations were not taken during this episode, it is difficult to assess whether the model has sufficient VOC emissions. However, a review of the predicted O_3 concentrations indicates that there is sufficient reactivity in the model to produce reasonable levels of O_3 and that further increases in VOC emissions would likely lead to unrealistic O_3 concentrations. Therefore, we believe there are sufficient VOC emissions in the current emissions inventory.

Base 9: M2, EB04, V6

The purpose of this simulation was to assess the sensitivity of the model to changes in wind speed. Wind speeds were globally increased by 10%. In general, concentrations of all species decreased from those predicted for Base 7. While this simulation gave no insight into the under predictions of secondary PM_{10}, it does demonstrate how biases in wind speeds could explain, in part, the general over predictions of primary PM_{10}.

Base 10: M2, EB04, V6

The purpose of this simulation was to assess the sensitivity of the model to diffusion break changes. In the evaluation of Base 7 it was noted that UAM-AERO did reasonably well at predicting PM_{10} concentrations, when compared with TEOM data, until mid-day when the diffusion break rose quickly. In this simulation the diffusion break was set at a constant 100 m.

The results showed general decreases in late night and early morning PM_{10} concentrations. This was expected because previously the diffusion break was at the 80 meter minimum during these periods. During the daytime hours when the diffusion break had increased rapidly in Base 7 there were some increases in concentrations for most all species but the divergence from the observed PM_{10} increases remained. This is particularly evident in the region near the Air Monitoring Center (AMC) site in Salt Lake City. In addition the concentration of both primary and secondary species are predicted to drop during the late morning to early afternoon hours. This implies that the problem is not dominated by mixing heights or chemistry but rather by some other removal process such as diffusion, advection, or deposition.

Base 10a: M2, EB04, V6

The purpose of this simulation was to assess the sensitivity of the model to stability conditions when the diffusion break remained constant. It was noted in the METSCALARS file that the exposure class reached a value of 2 (B stability class) during the period of concern. These values were reduced to a value of 1 (C stability class) for this simulation to reduce the modeled diffusion and deposition. These changes had very little impact on the simulation.

Base 10b: M2, EB04, V6

Based on discussions about what the stability is really like during these conditions, the daytime exposure class values were reduced to a value of 0 (D/neutral stability). These changes had very little impact on the simulation.

Base 10c: M2, EB04, V6

To complete our investigation of impacts of exposure class on model predictions the daytime exposure class values were reduced to a value of –1 (E stability). Once again these changes had very little impact on the simulation. The results of the Base 10/10a/10b/10c simulations, in combination with the Base 6c deposition sensitivity simulation, have helped to eliminate many of the possible explanations for the model's under prediction of secondary nitrate aerosol.

Base 11: M2, EB04, V6

The purpose of this simulation was to assess the sensitivity of the model to water concentrations. During the analysis of Base 7 we questioned whether there was enough reactivity in the system and speculated that the model might not be producing enough OH radicals. One of the pathways for OH radical formation is the reaction of O^1D with H_2O. It had been noted that the water concentrations predicted by MM5 seemed low. In this simulation the water concentrations were globally increased by a factor of two. In problem areas (i.e., near the AMC) this resulted in NO3.1 increases on the order of 1 $\mu g/m^3$, which is larger than the doubling of VOC produced but does not contribute significantly to resolving the NO3.1 under predictions.

Base 12: M2, EB04, V6

The purpose of this simulation was to assess the sensitivity of the model to the fog index. Certain reactions in the aerosol chemistry are accelerated under fog conditions and we speculated that these conditions could be more important in this type of episode. The fog index was set to a value of 3 for all cells and all hours to indicate that fog was present. This resulted in an increase in NO3.1 of 1 to 2 $\mu g/m^3$ at the AMC. This is larger than the doubling of water produced but does not contribute significantly to resolving the NO3.1 under predictions. This simulation also resulted in significant increases in secondary sulfate aerosol (SO4.1). At the AMC, SO4.1 increased by 4 to 7 $\mu g/m^3$. These increases are consistent with the model formulation. However, this sensitivity resulted in a significant over prediction of SO4.1 at the AMC, which indicates that increases in the fog index are not warranted.

The following sensitivity runs, Base 13 through Base 25, incorporate emissions fields which were later found to be incorrect. The changes made in these runs which are used in the development of the final base case are discussed, but the emissions themselves are not.

Base 13: M3, EB04, V6

The purpose of this simulation was to incorporate a relative humidity based algorithm for the prediction of the presence of fog in the model. The fog fields are based on relative humidity, except where no meteorological station is available within 25 km or the MM5 surface elevation is less than 1500 meters, in which case the fog scheme is the same as that used previously. The criteria for determining the presence of fog based on relative humidity is as follows:

RH = 90% indicates fog;
60% = RH < 90% indicates haze;
RH < 60% indicates that the area is clear.

The fog algorithm is used in the following runs and results are discussed below.

Base 14: M4, EB04, V6

This run included modifications in the meteorological fields and air quality initial conditions and boundary conditions. The bias was removed from the temperature and relative humidity fields. The diffbreak was regenerated based on the new temperature fields and then the winds were remapped to the vertical layers dictated by the diffbreak. The fog fields were based on observed relative humidity following the same conventions as in Base 13. New initial condition, boundary condition, and top concentration fields were generated based upon the new meteorological fields. Additionally, a new metscalars file was used which includes a corrected time shift (the sun was rising too early); applies a more appropriate atmospheric pressure; and applies a more realistic exposure class.

The improvements incorporated in Base 14 were used in future runs. Results will be discussed below.

Base 15-18: Incorrect emissions

Base 20: M4, EB10, V6

Emissions were reprocessed using the IDA format rather than the EMS-95 format. Annual emissions were allocated based upon temporal profiles. Mobile emissions were calculated using Mobile 6.

Base 21 (not run – no difference in emissions totals due to using day specific emissions for specific point sources).

Base 22: M4, EB12, V6

This run includes “pseudostacks” for those point sources which do not have stacks but which may emit above the lowest layer of the modeling domain. We chose large sources of emissions coming out of big buildings as psuedostacks. These included cooling towers at Kennecott and coke oven leaks and roof vents at Geneva Steel. The stack parameters were estimated using the area of the emission point and an assumption that the exit velocity was 1 ft/sec unless otherwise specified.

Base 24: M5, EB10, V6

This run incorporated new wind fields that were created using a combination of wind fields from the Diagnostic Wind Model (DWM) and from MM5.

Base 25: M5 (winds only), EB13, V6

The speciation profiles for sulfate, organic carbon, elemental carbon, and salt (NaCl) were improved for this run. . In addition, sulfate (SO_4) is prescribed to be emitted into the airshed as 1.5% of SO_2 emissions.

Base 26: M5 (winds only), EB14, V6b

The stack exit velocities had been calculated incorrectly for EB10-EB13. This is corrected for EB14. Additionally, some corrections were made in the Mobile 6 runs. This model version (6b) has modified SO_2 ? H_2SO_4 reaction rates in the empirical fog model.

At this point in the base case development, total PM_{10} was over predicted, largely due to over prediction of OTR. Secondary particulates (NO_3, Na, Cl) were under predicted except for SO_4 which was greatly over predicted.

Base 27: M5 (winds only), EB15, V6b

Emissions base 15 incorporated pseudostacks into the point source file for EB14. The incorporation of pseudostacks had very little impact on model results.

Base 28: M5 (winds only), EB16, V6b

Emissions base 16 incorporated improved speciation profiles for sulfate, organic carbon, elemental carbon, and salt. In addition, the amount of sulfate (SO_4) emitted into the airshed is prescribed to be 1.5% of SO_2 emissions.

The results of the changes in speciation profiles and in sulfate allocation turned a large sulfate over prediction into a slight under prediction. These changes also improved the relative amounts of the PM_{10} species.

(Include b28 sensitivities on neutral stability, fugitive dust, wood smoke, fixed diffbreak?)

Base 29: M5 (winds only), EB17, V6b

Emissions base 17 incorporated a number of changes: ptsrce code fixed for processing elevated point sources; non-operating Kennecott boilers and associated cooling towers removed; 80% dust control for uncontrolled fugitive point sources; altered oxy fuel program in Utah county; corrected road dust calculation in Mobile6; fixed area source temporal allocations; include process specific speciation profiles for some processes which were using default speciation profiles; applied 80% woodsmoke control for the red woodburn program.

The results of Base 29 are not very different from Base 28 but this was a watershed run because it incorporated so many fixes to the emissions processing.

Base 29b: M5 (winds and diffbreak), EB17, V6c

Version 6c of the model contains a modification to force neutral stability over urban areas at night as a result of anthropogenic heat flux and surface roughness (references: Duckworth & Sandberg, 1954; Demarrais, 1961).

Incorporation of Version 6c of UAM-AERO alters the behavior of the model significantly. As a result of neutral stability in urban areas at night, the over prediction of particular species disappears. The model now under predicts all species by approximately similar amounts. This creates more realistic model performance because the distribution of species is more realistic.

From this point on, the base case development included incorporation of a self-consistent set of meteorology which included the combination wind fields (MM5 for upper layers and DWM for the lower two layers of the model domain); fog fields prescribed by observed relative humidity; and diffbreak developed based on ABLM except for the Salt Lake City area which approximates the diffbreak generated from AMC SODAR observations. The changes in the emissions inventory from here on were small, incremental changes applied to increase consistency between the base year inventory and future year inventories.

Base 30: M5 (winds and diffbreak), EB17, V6c

Point sources reprocessed using the new diffbreak file (this should have been done in b29b).

Base 30c: M5 winds, AMC SODAR diffbreak, EB17, V6c

AMC SODAR data used to create a diffbreak file.

Base 31: M5, EB17, V6c

The M5 wind fields are used with diffbreak created from the Atmospheric Boundary Layer Model (ABLM). The Salt Lake City area is treated as a separate urban land use category in ABLM to approximate the AMC SODAR diffbreak observations.

Base 32: M6, EB17, V6c

The diffbreak fields from b31 were used to vertically map all of the other meteorological fields. The winds include results from the DWM for layers 1-2 and results from the MM5 for layers 3-5. Temperature, fog, and water content were calculated as before but are mapped vertically using the new diffbreak. Temperature and water content have bias correction implemented, and fog uses available relative humidity surface observations to prescribe fog or haze (see description for b13). Winds were then remapped based upon all of the above fields.

Base 32s1: M6, EB17s1, V6c

Emissions base 17 modified to include a 75% reduction in mobile road dust.

Base 32s2: M6, EB17s2, V6c

Emissions base 17 with doubled ammonia from cars.

Base 32s3: M6, EB17, V6c, modified IC/BC

Initial and boundary conditions modified to increase ammonia concentrations from 1 ppb to 5 ppb.

Base 33: M6, EB17s1, V7

Version 7 of the UAM-AERO code includes an increase in the SO_2 ? H_2SO_4 reaction rates, but they are still only 50% of the rates in the original model formulation. Additionally, Base 33 used the emissions from Base 32s1 which have a 75% reduction in mobile road dust. The reduction in mobile road dust further improved the relative amounts of the particulate species.

Base 34: M6, EB18, V7

This run incorporated an improved road dust speciation profile for mobile emissions. Additionally, initial and boundary conditions and top concentration ammonia were increased from 1 ppb to 4 ppb (not 5 ppb as in b32s3).

The following runs have small, incremental changes in area source emissions. The impact is not large in terms of overall model performance.

Base 35: M6, EB19, V7

Area sources were rerun with the appropriate temporal profiles for residential and industrial oil and gas heating.

Base 36: M6, EB20, V7

Area sources rerun with charcoal meat grilling added in as backcasted from the 1999 inventory.

Base 37: M6, EB21, V7

Area sources rerun with several SCC categories backcasted from 1999 inventory rather than calculated as they were in 1996. This change provided consistency between the methods of calculation.

Base 38: M6, EB22, V7

Area sources include a woodsmoke reduction of 83% on red woodburn days (rather than 80%). Mobile sources include the latest numbers obtained from Mountainland Association of Governments (MAG).

Model performance is evaluated based upon the results of Base 38.

Table 4-1. Observed PM_{10} and component species concentrations ($\mu g/m^3$)

Summary of Utah Observed PM_{10} Speciation for 2/14/96 and 2/15/96

Composition (mass)		24-hour average ug/m^3								
Date	**Site**	**PM_{10}**	**OTR**	**NO3**	**SO4**	**NH4**	**OM**	**EC**	**Cl**	**Na**
2/14/1996	N2	156.9	39.3	50.1	9.5	15.9	32.0	4.9	3.1	2.0
2/14/1996	OG	97.0	36.3	24.9	3.7	7.6	17.0	4.9	1.4	1.2
2/14/1996	WO	108.7	50.7	24.7	3.0	6.1	16.2	4.8	2.5	0.8
2/14/1996	LN	146.7	79.2	30.2	3.4	8.2	18.5	3.2	2.9	1.2
2/14/1996	NP	120.1	51.8	28.5	3.0	7.6	22.2	4.1	1.9	1.2
2/15/1996	AM	148.3	37.6	47.8	6.2	14.7	29.0	6.8	4.1	2.2
2/15/1996	B4	92.2	12.4	45.6	5.5	13.8	10.1	2.3	2.2	0.3
2/15/1996	BT	104.0	24.7	38.1	6.0	12.7	16.1	3.7	1.8	0.9
2/15/1996	CW	129.9	30.9	48.7	5.7	15.4	22.9	3.1	2.2	1.2
2/15/1996	MG	78.4	15.7	35.8	4.5	11.1	6.7	3.9	0.2	0.5
2/15/1996	N2	161.1	29.3	60.3	9.7	19.5	34.5	3.5	3.0	1.4
2/15/1996	OG	95.7	29.5	30.2	3.5	8.8	15.5	5.4	1.8	1.0

4.2 Initial and Boundary Conditions

The UAM-AERO model requires that the chemical concentrations of both gaseous and aerosol species be specified for the initial time of the model simulation and at all horizontal and vertical boundaries for all hours of the simulation. Because of limited observational data, the ability to simulate two days before the period of interest, and the low wind speeds during the episode, initial and boundary conditions (horizontal and vertical) were set to typical background concentrations for all times.

Gaseous species background concentrations were on based the EPA default values suggested for photochemical modeling (U.S. EPA, 1991). One modification to those values was to increase the value for ammonia (NH_3) from 1 ppb to 4 ppb. EPA suggests 1 ppb for NH_3 and that value has historically been used for simulations of summertime ozone where ammonium sulfate and nitrate are not considered. The 4 ppb NH_3 concentration represents the high range for background air during winter and was shown in sensitivity simulations to provide a better representation of ammonium nitrate concentrations in rural areas. The adjusted initial and background concentrations for gaseous species are shown in **Table 4-1**. A limited number of historical ozone observations were available for February at national parks outside the modeling domain. A review of those observations showed concentrations of ozone typically ranging from 30 to 50 ppb.

Initial and background concentrations for aerosol species were based on a typical background PM_{10} concentration of 15 $\mu g/m^3$ and are summarized in **Table 4-2**. The PM_{10} concentration was speciated based on the observed speciation during the episode at a rural site. A minimum value of 0.1 $\mu g/m^3$ was used to prevent any potential numerical problems in the model due to zero concentrations. Finally, the chloride concentration was adjusted by performing an ion balance calculation to ensure the aerosols were electrically neutral.

Table 4-2. Concentrations of gaseous species used for initial and boundary conditions

CB-IV Species	Concentration (ppb)	CB-IV Species	Concentration (ppb)
OLE	6.00	H2O2	1.01
PAR	149.40	HNO3	0.01
TOL	1.26	MEOH	0.10
XYL	0.78	ETOH	0.10
FORM	2.10	O3	40.00
ALD2	1.11	NO2	2.000
ETH	1.02	NO	0.10
CRES	0.01	CO	350.00
MGLY	0.01	ISOP	0.10
OPEN	0.01	NH3	4.00
PNA	0.01	SO2	0.10
PAN	0.01	OLE2	0.01
HONO	0.01		

Table 4-3. Concentrations of aerosol species used for initial and boundary conditions

CB-IV Species	Concentration ($\mu g/m^3$)
H.1	0.00001
H2O.1	1.00000
OC.1	1.05000
EC.1	0.45000
OTR.1	13.3410
SO4.1	0.10000
CL.1	0.15400
NO3.1	0.20000
NH4.1	0.09550
NA.1	0.10000

5.0 Diagnostic Tests

Diagnostic tests are used to explain model performance and to provide clues about how to improve reliability of predictions. These tests are performed using one of two broad approaches, sensitivity tests and process analysis. The first approach consists of tests in which sensitivity of air quality predictions to perturbations in one or a combination of model inputs is examined. This is the more traditional of the two approaches and was used in this modeling study. The second approach, process analysis, is not available with UAM-AERO.

5.1 Tests Performed

The diagnostic sensitivity tests performed during the base case development are summarized in **Table 5-1** where concentration changes noted in the results column generally refer to hourly concentrations. As noted in the discussion of the base case development, the initial simulations performed poorly. Diagnostic tests were used to explore the causes and potential solutions to the model's performance problems. By the time simulation base case 34 (B34) was performed, model performance had improved sufficiently and a series of final base case sensitivity simulations were performed to systematically explore the model's response to changes in inputs. These final base case sensitivity runs were used to verify that the model performed as expected under varied circumstances. These simulations are discussed in detail in the discussion of model performance evaluation (Chapter 6, Table 6-17 and Figures 6-15 through 6-33).

5.2 Consistency with Scientific Understanding and Expectations

The diagnostic sensitivity simulations performed involved changes to model inputs or options in one or more of 10 categories of inputs. In all cases, the response of the modeling system was consistent with our scientific understanding of the processes leading to elevated PM_{10} concentrations in the Salt Lake and Utah valleys. Each of these categories is discussed below. Some of these results are verified further from results of the final base case sensitivity runs discussed in Chapter 6.

1. Horizontal grid resolution: Horizontal grid resolution had little impact on simulated concentrations except in the immediate proximity of large primary PM_{10} emission sources. Because some larger sources (e.g., Geneva Steel) cover areas greater than a 2-km grid cell, model performance was degraded at this finer resolution.
2. Primary PM_{10} emissions: As expected, concentrations of primary PM_{10} varied in direct proportion to changes in primary PM_{10} emissions.
3. Secondary PM_{10} precursor emissions: Reduction of NH_3 and NO_x emissions resulted in lower peak concentration of NO3.1. However, NO_x reductions also produced increases in NO3.1 in some areas. While this was not consistent with our initial expectations, it is consistent with our scientific understanding, which is discussed in the next subsection.
4. Boundary conditions: Changes to boundary concentrations had little effect on concentrations in the central portion of the domain. The increase of NH_3 boundary concentrations from 1 ppb to 5 ppb improved the model's prediction of secondary aerosols at sites outside the urbanized areas.
5. Wind speed: As expected, increased wind speeds decreased concentrations while decreased wind speeds increased concentrations.

Table 5-1. Summary of diagnostic sensitivity simulations performed during development of the base case

Case	Sensitivity	Result
B4b	Initial and boundary concentration ion balanced	Little effect.
B5	The same as b4c but at 4 km resolution	Little effect.
B6	Uses deposition option for snow on the ground and photolysis rates recalculated at an albedo of 45%	Increased PM_{10} in rural areas. Increased NO3.1 production.
B6b	Base 6 but with the photolysis rates doubled	Little effect.
B6c	Base 6b but with zero deposition	Little effect.
B8	Low-level VOC emissions doubled	Increased NO3.1 by a few percent.
B9	Wind speeds increased by 10%	5-15 $\mu g/m^3$ decrease in PM_{10}.
B10	Diffusion break set at 100 m for all cells all hours	General decrease in late night and early morning PM_{10}.
B11	Water content doubled	HNO_3 and aerosols greater.
B12	Fog in all cells	HNO_3 and aerosols greater.
B28s1	Forced neutral stability in Salt Lake City at night.	Reduced nighttime PM_{10} concentrations in Salt Lake City. Improved model performance.
B28s2	Mobile fugitive dust reduced by 50%	Significant reduction in primary PM_{10}.
B28s3	Wood smoke emissions reduced by 50%	10 - 40 $\mu g/m^3$ decreases in PM_{10} at night in Salt Lake City and Ogden.
B28s4	Diffusion break set at 100 m for all cells all hours	Pollutant concentrations peaked on the last day of the episode rather than the third day.
B32s1	75% reduction in mobile road dust; new road dust profile	Reduced OTR.1 and OC.1/EC.1; generally improved fractional speciation.
B32s2	Double NH_3 from mobile sources	Little effect.
B32s3	Increased initial and boundary concentrations of ammonia from 1 ppb to 5 ppb	PM_{10} increases by up to 12 $\mu g/m^3$ in the western portion of the domain and over the Wasatch and eastern portions of the Wasatch Front. There doesn't appear to be much increase in the populated areas of Salt Lake County but there is a difference in non-mountainous Utah County. A significant portion of this change is attributed to NO3.1.
B33	Reaction rate for SO_2 to H_2SO_4 set to 50% of that in original model formulation	Better SO4.1 performance in Salt Lake valley, little change in Utah valley.

6. Mixing depth: Changes to the height of the diffusion break resulted in significant changes to PM_{10} concentrations that were consistent with the change in mixing volume.
7. Stability: Stability had its greatest impact on nighttime concentrations in areas with primary emissions of PM_{10}. The specification of neutral stability in the urban core of Salt Lake City was consistent with prior studies on the effect of building roughness and anthropogenic heat flux, and resulted in improvements in model performance.
8. Fog: The presence of fog at night accelerated the production of nitric acid and ammonium nitrate. The presence of fog also increased deposition rates.
9. Deposition: Significant increases in PM_{10} concentrations were noted when deposition was eliminated in the model, which indicated its importance in achieving a proper mass balance. The use of deposition parameters for winter snow conditions resulted in minor increases in PM_{10} concentrations in rural areas.
10. Photolysis rates: Increasing photolysis rates based on the albedo of snow covered ground increased secondary aerosol formation rates.

5.3 Summary of Final Base Case Simulation

Based on the results of the diagnostic simulations performed and the model performance evaluations, a final base case simulation was made. This final simulation was base case 38 (B38) and is summarized as follows:

- Model: UAM-AERO Version 6, which includes corrected aerosol concentration conversions, treatment of deposition for winter snow conditions, neutral nighttime stability for highly urbanized areas, and reduced SO_2 to H_2SO_4 reaction rates in the empirical fog chemistry sub-model.
- Grid resolution and structure: 33x56 cells with 4-km grid spacing. Five vertical levels from the ground to 2000 m; 2 layers below the diffusion break with a minimum thickness of 40 m; 3 layers above the diffusion break with a minimum thickness of 200 m.
- Aerosol chemistry: ISOROPIA-PLUS thermodynamic equilibrium aerosol model, 10 aerosol species, and one size section (PM_{10}).
- Photolysis rates: Calculated based on an albedo of 45% for snow covered ground.
- Initial and boundary conditions: EPA defaults for gaseous species except NH_3, which was increased to 4 ppb on the boundaries. PM_{10} concentration set to 15 $\mu g/m^3$ with speciation based on rural measurements.
- Temperature, pressure, water concentration: Penn State/NCAR mesoscale model (MM5).
- Winds: Hybrid MM5 and Diagnostic Wind Model (DWM). DWM used for the bottom two model layers.
- Diffusion break: Calculated diagnostically with the Atmospheric Boundary Layer Model (ABLM) using MM5 meteorology and DWM winds.
- Fog: Presence of fog diagnosed from relative humidity and terrain elevation.
- Sulfate aerosol emissions: Prescribed as 1.5% of SO_2 gas emissions.

- Mobile source emissions: MOBILE6/PART5.
- Road dust emissions: Modified emission factors based on a Denver study on salting/sanding and revised speciation profiles based on local measurements. Uncontrolled emissions from unpaved roads were reduced by 80% due to snow cover and/or wet road conditions.

Detailed descriptions of the preparation of meteorological, air quality, and emission inputs for this base case were described previously. In the following section, model performance for the final base case is discussed.

6.0 Model Performance Evaluation

6.1 Introduction

Because aerosol modeling is still in its infancy relative to photochemical ozone modeling, official guidance on model performance evaluation (MPE) is not available. The EPA has developed a guidance document for ozone model performance evaluation (U.S. EPA, 1991) that suggests specific tests and comparisons, recommends graphical methods for use in interpreting and displaying results, and identifies potential issues or problems that may arise. Another document titled "Improvement of Procedures for Evaluating Photochemical Models," (Tesche et al., 1990) provides a comprehensive discussion of MPE procedures and issues and significantly influenced the EPA guidance document. More up-to-date guidance for ozone modeling (U.S. EPA, 1999a) is also available from EPA in draft form and includes suggestions on performance evaluation. In addition, EPA has developed draft modeling guidance for $PM_{2.5}$ (U.S. EPA, 2001). While none of these documents focus specifically on model performance for PM_{10}, the basic MPE concepts are applicable to PM_{10} aerosol models. An EPA concept paper (U.S. EPA, 1999b) also provides some insight, albeit for modeling the fine fraction, on evaluating model performance.

The objective of this MPE was to determine if the UAM-AERO simulations performed for this study can be used to demonstrate attainment of the National Ambient Air Quality Standards (NAAQS) for PM_{10}. In performing the evaluation, we tried to answer the following questions:

- How close does the model simulate observed concentrations?
- What biases are exhibited by the model? What are the causes?
- What are the model's sensitivities and can they be quantified?
- Does the model respond, in direction and magnitude, to emissions changes in such a way that enables decision-makers to confidently use the model for policy development?

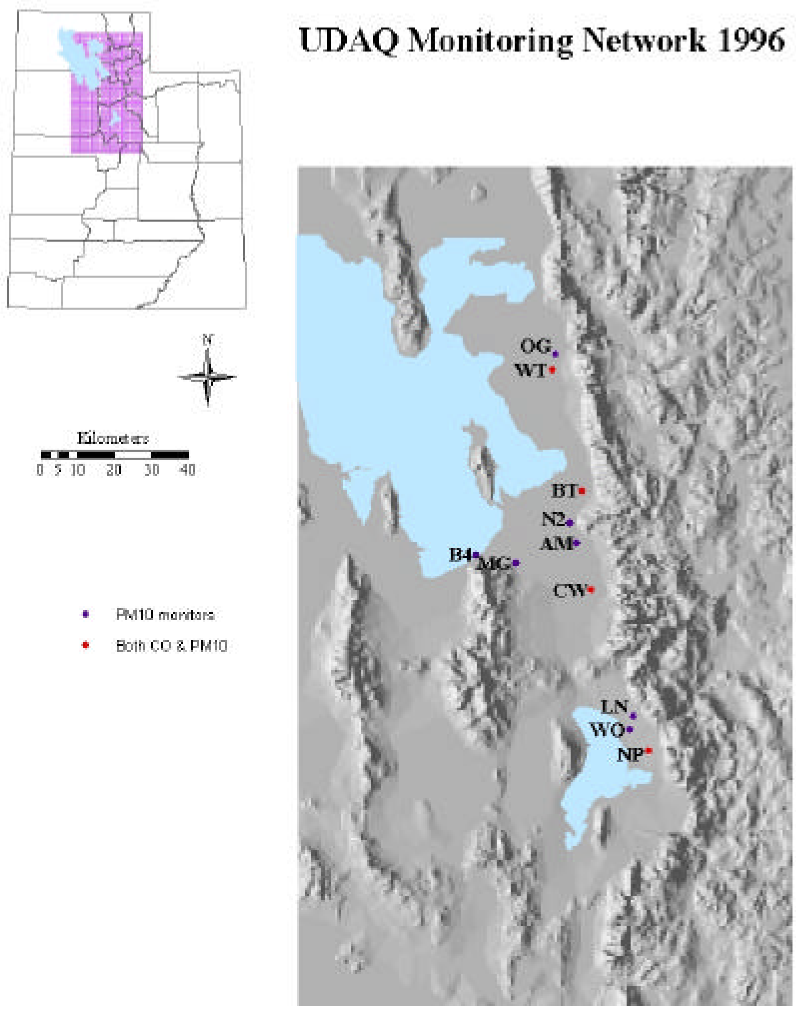
6.2 Summary of Observational Data Available

Air quality monitoring data for the episode is limited but sufficient to carry out the model performance evaluation. The monitoring sites with data during the episode are identified in **Figure 6-1**. A summary of available measured gaseous and aerosol species, the sites where they were measured, and the associated UAM-AERO species names are provided in **Table 6-1**.

During the five-day period simulated with UAM-AERO, 43 PM_{10} filter samples were taken at 11 sites. Of these 43 samples, 13 underwent analysis to provide chemical speciation. The chemical analysis provided detailed speciation, which was then mapped to the aerosol species in UAM-AERO. These measurements are shown in **Table 6-2**. In processing the observed speciated PM_{10}, mass that was unidentified in the chemical analysis was added to UAM-AERO's "other" component (OTR.1). The amount of unidentified mass for samples taken during the episode ranged from 9.4% to 42.0%. If unidentified mass contains significant amounts of non-OTR.1 components, observations will over-estimate OTR.1 and under-estimate non-OTR.1 components. An analysis of the ratio of positive to negative ions was performed on the speciated samples. The observed ion ratios ranged from 0.74 to 0.94. Acceptable ion ratios typically range from 0.90 to 1.10. Most of the samples taken at sites in Salt Lake County are within this range. Sites in Utah County had the lowest ratios, ranging from 0.74 to 0.83. The results of the ion balance analysis indicate that some of the unidentified mass in these samples may have been positive ions.

Hourly $PM_{2.5}$ observations from tapered element oscillating microbalance (TEOM) samplers at three sites (AM, LN, and OG) were available. The AMC performed a correlation analysis of PM_{10} and $PM_{2.5}$ samples and provided estimates of hourly PM_{10} based on the analysis. Hourly carbon monoxide (CO) samples were available at six sites while oxides of nitrogen (NO and $NO_{2)}$ and sulfur dioxide (SO_2) samples were available at four sites each.

Because of the limited number of NO, NO_2, and SO_2 samples and the unavailability of ozone (O_3) measurements during the episode, these species were only evaluated informally. However, the CO measurements were used to help evaluate mixing characteristics represented in UAM-AERO.



AM – Air Monitoring Center (AMC)
B4 – Beach
BT – Bountiful
CW – Cotton Wood
LN – Lindon
MG – Magna
N2 – North Salt Lake
NP – North Provo
OG – Ogden
WO – West Orem
WT – Washington Terrace
O2 – Orem
SO – South Orem
U2 – Provo University Ave
U3 – University Avenue #3

Figure 6-1. Air quality monitoring sites in the modeling domain

Table 6-1. Chemical constituents available for the aerosol model performance evaluation

Constituent	Description	Sites	UAM-AERO Name	Units
$PM_{2.5}$ Mass	Hourly Particulate Matter < 2.5 µ	AM, LN, OG	N/A	µg/m^3
PM_{10} Mass	Particulate Matter < 10 µ	AM, B4, BT, CW, LN, MG, N2, NP, OG, WO, WT	PM10	µg/m^3
PM_{10} SO_4	Sulfate < 10 µ	AM, B4, BT, CW, LN, MG, N2, NP, OG, WO, WT	SO4.1	µg/m^3
PM_{10} NO_3	Nitrate < 10 µ	AM, B4, BT, CW, LN, MG, N2, NP, OG, WO, WT	NO3.1	µg/m^3
PM_{10} NH_4	Ammonium < 10 µ	AM, B4, BT, CW, LN, MG, N2, NP, OG, WO, WT	NH4.1	µg/m^3
PM_{10} OC	Organic Matter < 10 µ	AM, B4, BT, CW, LN, MG, N2, NP, OG, WO, WT	OC.1	µg/m^3
PM_{10} EC	Elemental Carbon < 10 µ	AM, B4, BT, CW, LN, MG, N2, NP, OG, WO, WT	EC.1	µg/m^3
PM_{10} CL	Chloride < 10 µ	AM, B4, BT, CW, LN, MG, N2, NP, OG, WO, WT	CL.1	µg/m^3
PM_{10} NA	Sodium < 10 µ	AM, B4, BT, CW, LN, MG, N2, NP, OG, WO, WT	NA.1	µg/m^3
Other PM_{10}	Other particulate matter < 10 µ	AM, B4, BT, CW, LN, MG, N2, NP, OG, WO, WT	OTR.1	µg/m^3
NO	Hourly Nitrogen Oxide	BT, CW, NP, OG	NO	ppm
NO_2	Hourly Nitrogen Dioxide	BT, CW, NP, OG	NO2	ppm
SO_2	Hourly Sulfur Dioxide	B4, BT, CW, N2	SO2	ppm
CO	Hourly Carbon Monoxide	NP, O2, SO, U2, U3, CW	CO	ppm

Table 6-2. Observed 24-hr average PM_{10} concentrations ($\mu g/m^3$)

SITE	DATE	PM10	OTR.1	NO3.1	SO4.1	NH4.1	OC.1	EC.1	CL.1	NA.1
AM	960211	69.0								
AM	960212	98.0								
AM	960213	125.0								
AM	960214	151.0								
AM	960215	148.3	37.6	47.8	6.2	14.7	29.0	6.8	4.1	2.2
B4	960211	41.0								
B4	960213	66.0								
B4	960215	92.2	12.4	45.6	5.5	13.8	10.1	2.3	2.2	0.3
BT	960211	51.0								
BT	960213	81.0								
BT	960215	104.0	24.7	38.1	6.0	12.7	16.1	3.7	1.8	0.9
CW	960211	58.0								
CW	960213	107.0								
CW	960215	129.9	30.9	48.7	5.7	15.4	22.9	3.1	2.2	1.2
LN	960211	70.0								
LN	960212	125.0								
LN	960213	141.0								
LN	960214	146.7	79.2	30.2	3.4	8.2	18.5	3.2	2.9	1.2
LN	960215	129.0								
MG	960211	35.0								
MG	960212	43.0								
MG	960213	68.0								
MG	960214	88.0								
MG	960215	78.4	15.7	35.8	4.5	11.1	6.7	3.9	0.2	0.5
N2	960211	99.0								
N2	960212	99.0								
N2	960213	143.0								
N2	960214	156.9	39.3	50.1	9.5	15.9	32.0	4.9	3.1	2.0
N2	960215	161.1	29.3	60.3	9.7	19.5	34.5	3.5	3.0	1.4
NP	960211	60.0								
NP	960212	95.0								
NP	960213	101.0								
NP	960214	120.1	51.8	28.5	3.0	7.6	22.2	4.1	1.9	1.2
NP	960215	109.0								
OG	960211	55.0								
OG	960212	55.0								
OG	960213	72.0								
OG	960214	97.0	36.3	24.9	3.7	7.6	17.0	4.9	1.4	1.2
OG	960215	95.7	29.5	30.2	3.5	8.8	15.5	5.4	1.8	1.0
WO	960214	108.7	50.7	24.7	3.0	6.1	16.2	4.8	2.5	0.8
WT	960211	27.0								
WT	960213	60.0								
WT	960215	79.6	26.0	26.7	3.3	7.8	9.7	5.0	0.5	0.6
	Average	93.9	35.7	37.8	5.2	11.5	19.2	4.3	2.1	1.1
	Minimum	27.0	12.4	24.7	3.0	6.1	6.7	2.3	0.2	0.3
	Maximum	161.1	79.2	60.3	9.7	19.5	34.5	6.8	4.1	2.2

6.3 Model Performance Tests and Criteria for this Study

There are no universal acceptance criteria in photochemical modeling. Multiple statistics are used together with graphical displays to evaluate photochemical models because no one measure is adequate for characterization of performance. An attractive approach for determining "acceptance" of a model is for acceptance to be derived from a lack of rejection in a series of planned tests. Tentative acceptance can be the result of many "nonrejections" in a prescribed evaluation process where both statistical comparisons with observed concentrations and graphical evaluation of predicted and observed patterns are considered. Acceptance is tentative because we can never have complete information; rather, evidence builds to the point where we become comfortable with the prospect of a model being judged adequate in light of available information.

A common problem in urban and regional modeling is that the model generates spatial patterns of pollutants that may be similar to the observed patterns. However, they may be shifted in time and/or space (elongated or broadened). Pattern recognition may be useful for analysis of spatial and temporal patterns. The classic statistical approaches to MPE do not provide sufficient information about the similarity of the spatial patterns, which could be useful in assessing performance. Because pattern recognition software has not been sufficiently tested for use with air quality data and there is little observational data available, we relied upon subjective pattern recognition in this MPE. Emphasis was placed on graphical analyses, and evaluations relied upon the modeling team's scientific understanding of the processes responsible for aerosol formation in the study region.

Multi-pollutant evaluations are particularly important for evaluating the performance of photochemical PM models. The same statistical measures of performance are generally used for all species; however, the criteria for rejection as well as the importance of certain measures may differ. Comparisons should be made for the major precursors and products. Clearly, reactive models that simulate precursor and product species well are much less likely to be flawed than models that only simulate a single product species well. Often, the observational databases lack sufficient species to carry out detailed multi-pollutant evaluations, which was the case in this study.

For evaluating performance of an aerosol model, such as UAM-AERO, chemical composition and size distribution of the aerosols should be considered. Evaluation of aerosol mass alone is not sufficient.

Photochemical aerosol modeling is more uncertain than photochemical ozone modeling for many reasons:

- There are greater uncertainties in emission inventories for particulate matter (PM)
- Less is known about the physical and chemical processes contributing to aerosol formation and growth
- Observations of aerosols are more uncertain than observations of ozone
- Fewer observations are available to understand the spatial, chemical, and size distribution of aerosols in the ambient atmosphere and to use in model MPE

This last point is particularly important. If we had only one observation of 24-hr average PM_{10} mass and could get perfect statistical performance at that location, there would still be a high level of uncertainty in the model's ability to correctly predict the response of PM_{10} formation to changes in the emission inventory. Only by making sure the model performs well for many locations and many predicted variables do we reduce uncertainty and gain confidence in the model's predictive ability. In the case of this PM_{10} modeling study, speciated data exist for only two days with virtually no temporally allocated measurements.

Much of the air quality community's experience in MPE has been with ozone. Historically, we have used photochemical ozone models to demonstrate attainment of the ozone NAAQS in an absolute sense. An absolute attainment demonstration is an approach that relies on verification that the model is performing within statistical limits determined by EPA. If the model performs to these standards, then the absolute values obtained from the base case and future-year scenarios are used to evaluate whether a future-year control strategy is sufficient for an area to attain the NAAQS. Typically, extensive field study data are used in model-input preparation and MPE for an absolute attainment demonstration. Unfortunately, we do not have extensive meteorological or air quality data to support an absolute attainment demonstration for the Wasatch Front PM_{10} aerosol modeling application.

Aerosol modeling is currently more uncertain than ozone modeling. Thus, we are unlikely to reach a level of confidence with aerosol modeling that will allow us to use it in an absolute sense. However, there may be cases where an aerosol model significantly under- or over-predicts PM concentrations, but the results of the MPE convince us that it is capable of predicting the correct response to emission changes. In that case, it may be possible to use the model predictions in a relative sense. Relative reduction factors similar to those proposed in EPA's draft guidance on ozone modeling (U.S. EPA, 1999a) could be generated for the PM components.

Because of the uncertainties associated with aerosol modeling, we propose two levels of testing and use for UAM-AERO. At the highest level, we propose tests and criteria that are comparable to those applied to ozone modeling applications. If the model performs well at this level, it would be reasonable to use the model in an absolute attainment demonstration. The rejection criteria at this level are summarized in **Table 6-3**. The following section on Model Performance Evaluation Methods and Issues provides a detailed discussion of the statistical measures, graphical procedures, and sensitivity analyses that are summarized here.

Table 6-3. Rejection criteria for UAM-AERO use in an absolute attainment demonstration

Tests	Rejection Criteria
Statistical	Statistics for 1-hr and 24-hr averaged $PM_{2.5}$ and PM_{10} (mass and chemical components), ozone, NO, NO_2, SO_2, NH_3, HNO_3, and VOCs are worse than EPA's ozone model performance criteria: • Normalized Mean Bias greater than +/- 15% • Normalized Mean Error greater than 35% • Unpaired Peak Prediction Accuracy greater than 20% Where bias and error are calculated for cases when the observed concentrations are greater than or equal to 10% of the maximum observed concentration during the modeled episode for each species.
Graphical	Modeled and observed species for the episode are not chemically, spatially, and/or temporally consistent.
Sensitivity	Responses for important secondary species inconsistent with our understanding of the processes leading to their formation.
Data	Type and/or quantity insufficient to perform statistical and graphical tests for all species indicated.

Based on the preliminary review of data available for evaluating the candidate episodes, we expect that it will be difficult to use UAM-AERO in an absolute attainment demonstration. There may be insufficient data to carry out the detailed statistical and graphical evaluations proposed. The alternative is to use UAM-AERO to calculate relative reduction factors for use in the attainment demonstration.

With data availability in mind, we have proposed performance criteria for the relative use of UAM-AERO. The criteria are less stringent than those for use in an absolute attainment demonstration. However, they require that the tests provide consistent evidence that the model is capable of correctly predicting the response of PM_{10} concentrations to changes in the emission inventory. Because of data limitations, the evaluation at this level is more subjective and relies heavily on the modeling team's scientific understanding of aerosol formation and the model's ability to replicate important processes in this formation. **Table 6-4** summarizes the criteria that were used to reject or accept the use of UAM-AERO for calculating relative reduction factors to use in the attainment demonstration.

Table 6-4. Rejection criteria for UAM-AERO in a relative attainment demonstration

Tests	Rejection Criteria
Statistical	Statistics for 24-hr average chemical components of PM_{10}: • Normalized Mean Bias greater than +/- 50% • Normalized Mean Error greater than 50% Where bias and error are calculated for cases when the observed concentrations are greater than or equal 10% of the maximum observed concentration for each species. The differences between predicted and observed PM_{10} chemical component fractions are subjectively determined to be significant, and cannot be explained or significantly reduced through diagnostic analysis. Significant differences in the relative contributions of primary and secondary PM_{10} exist between observations and predictions.
Graphical	Modeled and observed species for the episode are not spatially and/or temporally consistent. Diurnal variation of the predicted sum of nonvolatile PM components is not consistent with TEOM observations. Observations and predictions of primary and/or secondary species appear spatially uncorrelated, and the lack of correlation cannot be explained. Spatial and/or temporal differences can be explained but indicate significant problems with the meteorological, emissions, or other inputs to the model.
Sensitivity	Response for secondary species is inconsistent with our understanding of the processes leading to their formation as described by a conceptual model developed in the scoping study. Initial or boundary conditions dominate model predictions of primary and/or secondary species. Model predictions of secondary species are unresponsive to changes in precursor emissions.
Data	Type and/or quantity are insufficient to perform statistical and graphical tests indicated above.

Failure at this level is basis for abandoning the use of UAM-AERO as the sole component of the attainment demonstration. Because the evaluation is carried out by chemical component, performance for primary and secondary PM_{10} may be accepted or rejected independently.

6.4 Model Performance Evaluation Methods and Issues

6.4.1 Statistical Evaluation

To quantify base case model performance, selected statistical calculations are prescribed to compare observed and simulated pollutant species concentrations at monitoring sites for which valid, representative data are available (Tesche et al., 1990). Simulated pollutant concentrations for each monitoring site were calculated by linearly interpolating pollutant concentrations from the center of each of the four adjacent grid cells. All statistics were calculated for each monitoring site for which observed concentrations were available, for each county, and for all monitoring sites within the modeling domain. Statistics were then calculated for all chemical species for which observations were available. Three statistical measures of model performance are recommended in the existing EPA guidance document.

1. Mean normalized bias (NBIAS in percent) where N includes all of the predicted (Pred) and observed (Obs) concentration pairs with observed concentrations above a threshold concentration from all stations in a region (or subregion) on a given day. Note the bias is defined as a positive quantity when the model estimate exceeds the observation.

$$NBIAS = \frac{100}{N} \sum_{i=1}^{N} \frac{(Pred^{i}_{x,t} - Obs^{i}_{x,t})}{Obs^{i}_{x,t}}$$

2. Mean normalized error (NERROR in percent)

$$NERROR = \frac{100}{N} \sum_{i=1}^{N} \frac{|Pred^{i}_{x,t} - Obs^{i}_{x,t}|}{Obs^{i}_{x,t}}$$

3. Accuracy of daily maximum concentrations at the station with the highest observed concentration unpaired in time (APEAK in percent)

$$APEAK = 100 \left(\frac{\text{Max}\, Pred_{xmax} - \text{Max}\, Obs_{xmax}}{\text{Max}\, Obs_{xmax}} \right)$$

6.4.2 Graphical Evaluation

Spatial pattern comparisons of predicted and observed ozone concentrations were included as a performance measure. Time-series plots and contour plots (ground-level isopleths) are very useful for displaying simulation results. Graphical analysis procedures used include

- Time-series plots comparing observed and simulated pollutant concentrations for all monitoring stations within the modeling domain.
- Time-series plots comparing observed concentrations with the minimum and maximum simulated concentrations in surrounding grid cells of a monitoring site.

- Contour plots showing simulated pollutant concentrations and observed concentrations for each hour and/or multi-hour interval.
- Tile plots showing differences between observed and simulated concentrations.
- Tile plots showing differences between diagnostic or sensitivity simulations and base case simulations.

6.4.3 Sensitivity Analysis

We define sensitivity analysis as an evaluation of the response of the model to variations in one or more of the model inputs. The purpose of sensitivity analysis is to determine which of the model inputs have significant impact on model output. Sensitivity analysis serves as a check on the air quality simulation by ensuring that the model behavior adequately reflects understood atmospheric and chemical processes.

The response of the photochemical grid model, represented by simulated pollutant concentrations at selected monitoring sites, was evaluated as model inputs were varied. The following sensitivity simulations were performed:

- Zero boundary conditions
- Zero anthropogenic emissions
- Zero and double particulate matter emissions
- Zero and double ammonia emissions
- Emissions reductions of 50% in nitrogen oxides
- Emissions reductions of 50% in reactive organic gases
- Emissions reductions of 50% in nitrogen oxides and in reactive organic gases
- Zero and double mobile source emissions
- Zero surface deposition
- Wind speeds increased and decreased by 25%
- Diffusion break height increased and decreased by 25%
- Zero fog and haze
- Fog at all times and locations
- Ammonia emissions reduced 50%

6.5 Model Performance Results

In this section the statistical and graphical performance of the base case simulation is presented and discussed. In addition, the results of model sensitivity simulations performed are summarized. Finally, overall model performance is discussed and recommendations for model use are presented.

6.5.1 Statistical Performance

The statistical performance for the base case simulation is presented for total 24-hr average PM_{10}, and its species components are presented in **Tables 6-6 through 6-13**. The three statistics shown are normalized bias (NBIAS), normalized error (NERROR), and accuracy of the peak prediction (APEAK). Caution should be exercised in interpreting these statistics, as the number of observation-prediction pairs is often small. Further, in processing the observed speciated PM_{10}, mass that was unidentified in the chemical analysis was added to the "other" component (OTR.1). The amount of unidentified mass for samples taken during the episode ranged from 9.4% to 42.0%. If the unidentified mass contains significant amounts of non-OTR.1 components, the observations will over-estimate OTR.1 and under-estimate non-OTR.1 components.

For purposes of this analysis, the model domain was split into three subregions: Salt Lake City, Utah County, and other areas to allow subregional analysis of performance statistics. The monitoring sites used for each of these subregions are shown in **Table 6-5**.

Table 6-5. Monitoring sites in each subregion

Subregion	Monitoring Sites
Salt Lake City	AM, CW, and N2
Utah County	LN, NP, and WO
Other	OG, WT, MG, BT, and B4

The statistics in Table 6-6 for PM_{10} mass alone show the criteria required for using the model in an absolute attainment demonstration are not met. Overall, PM_{10} mass performance met the goal for use in a relative attainment demonstration. However, the component performance (**Tables 6-7 through 6-15**) did not meet performance goals in the following areas:

1. Other PM_{10} (OTR.1): Outside Salt Lake City and Utah County on February 15, there was a large over prediction. A review of site-specific performance indicates this performance was dominated by an over prediction at MG
2. Sulfate (SO4.1): Outside Salt Lake City on February 14, there were under predictions greater than 50%.
3. Elemental Carbon (EC.1): The normalized error in Salt Lake City was 50.8% on the February 15. However, the concentrations are low.
4. Organic Carbon (OC.1): There was a general under prediction. A review of spatial plots suggests the OC.1 peak was displaced to the southeast of Salt Lake City. This under prediction should not be a major issue if relative reduction factors are used.
5. Sodium (NA.1) and Chloride (CL.1): Both components were over-estimated in Utah County. The road dust profile used in the base case simulation was selected to represent conditions in Salt Lake City a few days after snowfall and associated salting/sanding. The over prediction in Utah County is likely due to the use of that profile when snow was not present and salting did not occur.

Table 6-6. Performance statistics for 24-hr average PM_{10} mass. Peak concentrations are in $\mu g/m^3$

Date	Region	$Peak_o$	N	$Peak_p$	NBIAS	NERROR	APEAK
960211	Salt Lake City	99.0	3	51.1	-35.4%	35.4%	-48.4%
960211	Utah County	70.0	2	53.3	-19.2%	19.2%	-23.9%
960211	Other	55.0	5	65.1	24.6%	38.1%	18.4%
960211	All	99.0	10	65.1	-2.2%	33.5%	-34.2%
960212	Salt Lake City	99.0	2	76.3	-28.2%	28.2%	-22.9%
960212	Utah County	125.0	2	72.2	-37.3%	37.3%	-42.2%
960212	Other	55.0	2	84.7	50.3%	50.3%	54.0%
960212	All	125.0	6	84.7	-5.1%	38.6%	-32.2%
960213	Salt Lake City	143.0	3	142.3	-10.1%	32.1%	-0.5%
960213	Utah County	141.0	2	76.1	-46.4%	46.4%	-46.0%
960213	Other	81.0	5	96.7	10.1%	13.4%	19.4%
960213	All	143.0	10	142.3	-7.3%	25.6%	-0.5%
960214	Salt Lake City	156.9	2	110.5	-31.6%	31.6%	-29.6%
960214	Utah County	146.7	3	139.3	-19.8%	38.6%	-5.0%
960214	Other	97.0	2	100.3	1.9%	12.0%	3.4%
960214	All	156.9	7	139.3	-17.0%	29.0%	-11.2%
960215	Salt Lake City	161.1	3	110.1	-37.7%	37.7%	-31.7%
960215	Utah County	129.0	2	92.7	-36.0%	36.0%	-28.1%
960215	Other	104.0	5	96.6	-8.4%	17.7%	-7.1%
960215	All	161.1	10	110.1	-22.7%	27.4%	-31.7%

Table 6-7. Performance statistics for 24-hr average OTR.1 mass. Peak concentrations are in $\mu g/m^3$

Date	Region	$Peak_o$	N	$Peak_p$	NBIAS	NERROR	APEAK
960214	Salt Lake City	39.3	1	30.7	-22.0%	22.0%	-22.0%
960214	Utah County	79.2	3	84.0	-12.1%	55.8%	6.0%
960214	Other	36.3	1	35.3	-2.9%	2.9%	-2.9%
960214	All	79.2	5	84.0	-12.2%	38.4%	6.0%
960215	Salt Lake City	37.6	3	25.7	-22.4%	22.4%	-31.6%
960215	Utah County		0				
960215	Other	29.5	5	63.3	100.7%	103.9%	114.3%
960215	All	37.6	8	63.3	54.5%	73.4%	68.6%

Table 6-8. Performance statistics for 24-hr average NO3.1 (nitrate < 10 m) mass. Peak concentrations are in µg/m^3

Date	Region	$Peak_o$	N	$Peak_p$	NBIAS	NERROR	APEAK
960214	Salt Lake City	50.1	1	28.6	-42.9%	42.9%	-42.9%
960214	Utah County	30.2	3	21.2	-28.2%	28.2%	-29.7%
960214	Other	24.9	1	20.3	-18.5%	18.5%	-18.5%
960214	All	50.1	5	28.6	-29.2%	29.2%	-42.9%
960215	Salt Lake City	60.3	3	40.1	-45.6%	45.6%	-33.5%
960215	Utah County		0				
960215	Other	45.6	5	23.3	-42.0%	42.0%	-48.9%
960215	All	60.3	8	40.1	-43.3%	43.3%	-33.5%

Table 6-9. Performance statistics for 24-hr average SO4.1 (sulfate < 10 m) mass. Peak concentrations are in µg/m^3

Date	Region	$Peak_o$	N	$Peak_p$	NBIAS	NERROR	APEAK
960214	Salt Lake City	9.5	1	7.2	-24.4%	24.4%	-24.4%
960214	Utah County	3.4	3	1.2	-62.3%	62.3%	-64.5%
960214	Other	3.7	1	1.3	-64.5%	64.5%	-64.5%
960214	All	9.5	5	7.2	-55.2%	55.2%	-24.4%
960215	Salt Lake City	9.7	3	6.9	-5.7%	20.0%	-29.0%
960215	Utah County		0				
960215	Other	6.0	5	8.1	-13.6%	37.5%	34.6%
960215	All	9.7	8	8.1	-10.6%	30.9%	-16.7%

Table 6-10. Performance statistics for 24-hr average NH4.1 (ammonium < 10 m) mass. Peak concentrations are in µg/m^3

Date	Region	$Peak_o$	N	$Peak_p$	NBIAS	NERROR	APEAK
960214	Salt Lake City	15.9	1	11.0	-30.9%	30.9%	-30.9%
960214	Utah County	8.2	3	6.5	-14.6%	14.9%	-20.4%
960214	Other	7.6	1	6.3	-17.2%	17.2%	-17.2%
960214	All	15.9	5	11.0	-18.4%	18.5%	-30.9%
960215	Salt Lake City	19.5	3	14.3	-34.6%	34.6%	-26.7%
960215	Utah County		0				
960215	Other	13.8	5	9.3	-31.3%	31.3%	-32.7%
960215	All	19.5	8	14.3	-32.6%	32.6%	-26.7%

Table 6-11. Performance statistics for 24-hr average OC.1 (organic matter < 10 m) mass. Peak concentrations are in µg/m^3

Date	Region	Peak$_o$	N	Peak$_p$	NBIAS	NERROR	APEAK
960214	Salt Lake City	32.0	1	14.1	-56.0%	56.0%	-56.0%
960214	Utah County	22.2	3	10.4	-51.5%	51.5%	-53.1%
960214	Other	17.0	1	16.7	-1.5%	1.5%	-1.5%
960214	All	32.0	5	16.7	-42.4%	42.4%	-47.9%
960215	Salt Lake City	34.5	3	14.6	-55.8%	55.8%	-57.6%
960215	Utah County		0				
960215	Other	16.1	5	12.8	-22.6%	33.4%	-20.6%
960215	All	34.5	8	14.6	-35.0%	41.8%	-57.6%

Table 6-12. Performance statistics for 24-hr average EC.1 (elemental carbon < 10 m) mass. Peak concentrations are in µg/m^3

Date	Region	Peak$_o$	N	Peak$_p$	NBIAS	NERROR	APEAK
960214	Salt Lake City	4.9	1	5.6	13.5%	13.5%	13.5%
960214	Utah County	4.8	3	6.6	13.0%	32.0%	38.7%
960214	Other	4.9	1	4.8	-2.7%	2.7%	-2.7%
960214	All	4.9	5	6.6	10.0%	22.5%	33.8%
960215	Salt Lake City	6.8	3	5.9	29.0%	50.8%	-13.8%
960215	Utah County		0				
960215	Other	5.4	5	5.9	-15.7%	39.2%	9.2%
960215	All	6.8	8	5.9	1.1%	43.6%	-13.8%

Table 6-13. Performance statistics for 24-hr average CL.1 (Chloride < 10 m) mass. Peak concentrations are in µg/m^3

Date	Region	Peak$_o$	N	Peak$_p$	NBIAS	NERROR	APEAK
960214	Salt Lake City	3.1	1	1.5	-51.3%	51.3%	-51.3%
960214	Utah County	2.9	3	7.0	54.8%	76.3%	138.9%
960214	Other	1.4	1	1.4	0.5%	0.5%	0.5%
960214	All	3.1	5	7.0	22.7%	56.1%	127.5%
960215	Salt Lake City	4.1	3	2.1	-38.3%	38.3%	-48.5%
960215	Utah County		0				
960215	Other	2.2	5	1.4	133.8%	185.8%	-36.6%
960215	All	4.1	8	2.1	69.2%	130.5%	-48.5%

Table 6-14. Performance statistics for 24-hr average NA.1 (sodium < 10 m) mass. Peak concentrations are in µg/m^3

Date	**Region**	**Peak$_o$**	**N**	**Peak$_p$**	**NBIAS**	**NERROR**	**APEAK**
960214	Salt Lake City	2.0	1	1.0	-49.5%	49.5%	-49.5%
960214	Utah County	1.2	3	4.5	175.9%	191.0%	271.0%
960214	Other	1.2	1	1.0	-17.0%	17.0%	-17.0%
960214	All	2.0	5	4.5	92.2%	127.9%	127.2%
960215	Salt Lake City	2.2	3	1.2	-28.5%	29.2%	-45.3%
960215	Utah County		0				
960215	Other	1.0	5	1.0	40.5%	40.5%	0.6%
960215	All	2.2	8	1.2	14.6%	36.3%	-45.3%

6.5.2 Speciation

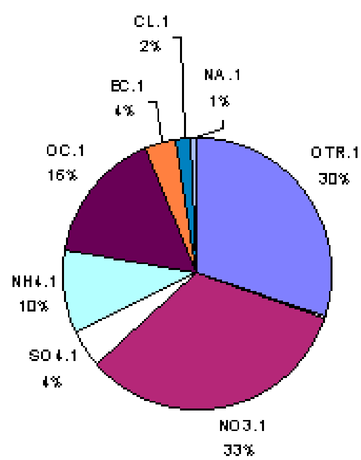
Tables 6-15 and 6-16 show observed and predicted PM10 speciation, respectively. **Figure 6-2** provides a comparison of observed and predicted average speciation over all sites and days with observations. Overall, the speciation looks reasonable. The predictions have more OTR.1 and less NO3.1 and OC.1 than observations. The lower fraction of NO3.1 may be a result of a spatial displacement of the NO3.1 peak in Salt Lake City. The observed peak is at the North Salt Lake (N2) monitor while the predicted peak is south and east of that site. Organic carbon (OC) in the model is emitted directly. The other primary components of PM_{10} do not exhibit the same speciation bias as OC; therefore, it is unlikely this bias is a result of biases in the meteorology. The lower OC fraction may be a result of either an under-estimation of the primary OC emissions or incorrect emissions speciation for sources that contribute OC.

Table 6-15. Observed PM_{10} speciation

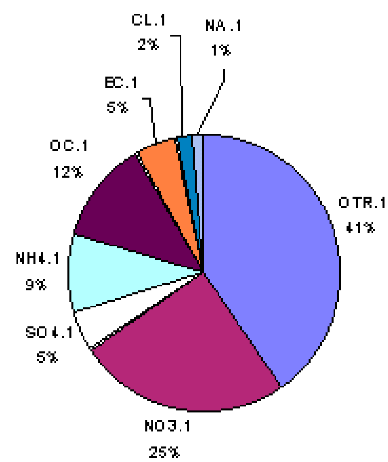
SITE	DATE	PM10 μg/m^3	OTR.1 %	NO3.1 %	SO4.1 %	NH4.1 %	OC.1 %	EC.1 %	CL.1 %	NA.1 %
AM	960215	148.3	25%	32%	4%	10%	20%	5%	3%	1%
B4	960215	92.2	13%	49%	6%	15%	11%	3%	2%	0%
BT	960215	104.0	24%	37%	6%	12%	16%	4%	2%	1%
CW	960215	129.9	24%	37%	4%	12%	18%	2%	2%	1%
LN	960214	146.7	54%	21%	2%	6%	13%	2%	2%	1%
MG	960215	78.4	20%	46%	6%	14%	9%	5%	0%	1%
N2	960214	156.9	25%	32%	6%	10%	20%	3%	2%	1%
N2	960215	161.1	18%	37%	6%	12%	21%	2%	2%	1%
NP	960214	120.1	43%	24%	2%	6%	18%	3%	2%	1%
OG	960214	97.0	37%	26%	4%	8%	17%	5%	1%	1%
OG	960215	95.7	31%	32%	4%	9%	16%	6%	2%	1%
WO	960214	108.7	47%	23%	3%	6%	15%	4%	2%	1%
WT	960215	79.6	33%	34%	4%	10%	12%	6%	1%	1%
	Average	116.8	30%	33%	4%	10%	16%	4%	2%	1%
	Maximum	161.1	54%	49%	6%	15%	21%	6%	3%	1%
	Minimum	78.4	13%	21%	2%	6%	9%	2%	0%	0%

Table 6-16. Summary of predicted PM_{10} speciation

SITE	DATE	PM10 $\mu g/m^3$	OTR.1 %	NO3.1 %	SO4.1 %	NH4.1 %	OC.1 %	EC.1 %	CL.1 %	NA.1 %
AM	960215	82.4	29%	29%	7%	11%	15%	6%	2%	1%
B4	960215	70.0	54%	18%	12%	10%	4%	2%	1%	0%
BT	960215	80.1	28%	29%	8%	12%	12%	7%	2%	1%
CW	960215	110.1	23%	36%	6%	13%	13%	5%	2%	1%
LN	960214	90.5	48%	23%	1%	7%	10%	5%	4%	2%
MG	960215	96.6	66%	16%	2%	5%	6%	2%	1%	1%
N2	960214	99.8	31%	29%	7%	11%	14%	6%	2%	1%
N2	960215	74.8	34%	26%	9%	11%	12%	6%	2%	1%
NP	960214	60.9	37%	31%	2%	10%	13%	5%	2%	1%
OG	960214	87.2	40%	23%	1%	7%	19%	6%	2%	1%
OG	960215	81.4	36%	28%	3%	9%	16%	5%	2%	1%
WO	960214	139.3	60%	14%	1%	4%	7%	5%	5%	3%
WT	960215	76.9	35%	28%	3%	9%	16%	6%	2%	1%
	Average	88.5	40%	25%	5%	9%	12%	5%	2%	1%
	Maximum	139.3	66%	36%	12%	13%	19%	7%	5%	3%
	Minimum	60.9	23%	14%	1%	4%	4%	2%	1%	0%



(a)



(b)

Figure 6-2. Comparison of (a) observed and (b) predicted average PM_{10} speciation for all sites on February 14 and 15, 1996

6.5.3 Spatial Plots

Figures 6-3 through 6-5 show the spatial distribution of 24-hr average PM predicted by UAM-AERO for February 13, 1996, through February 15, 1996, respectively. Panel (a) in these plots shows the total predicted PM_{10} mass concentration with observed values over-plotted. Panels (b), (c), and (d) show the predicted mass concentrations for primary, secondary, and nitrate PM_{10}, respectively. Primary PM_{10} includes the model species of OTR.1 (crustal/other), NA.1 (sodium), CL.1 (chloride), EC.1 (elemental carbon), and OC.1 (organic matter). Secondary PM_{10} includes the model species of NO3.1 (nitrate), SO4.1 (sulfate), and NH4.1 (ammonium). On each of these three days the peak observed concentrations are at the North Salt Lake (N2) site with elevated values also at the AM site.

When comparing the total PM_{10} with primary PM_{10}, it can be seen that the modeled domain peak concentrations are dominated by primary emissions at three locations: Geneva Steel in Utah County, the Kennecott Mine, and the Kennecott facilities near Magna. In general, the UAM-AERO is predicting the highest primary PM_{10} concentrations near these sites and within the urban areas of Salt Lake City, Provo, and Ogden.

Outside primary PM_{10} "hotspots" predicted by UAM-AERO, the peak PM_{10} mass concentrations are dominated by secondary PM_{10}. By comparing the secondary PM_{10} with the nitrate PM_{10} it can be seen that the secondary component of predicted PM_{10} is dominated by aerosol nitrate. The principal secondary aerosol formed in the UAM-AERO simulation is ammonium nitrate. If the NH4.1 concentrations are added to the NO3.1 concentrations, nearly all of the secondary PM_{10} is explained.

Secondary PM_{10} in the UAM-AERO predictions is distributed more widely than primary PM_{10} and consistently places a peak to the south and east of the observed peak. Significant secondary PM_{10} is predicted over the mountains into Wasatch County. During the type of conditions experienced in this episode, very little exchange of air between the Salt Lake valley and the mountains is observed. These features in the UAM-AERO simulation are likely due to transport and diffusion errors in the model and explain the under predictions at the N2 and AM sites in Salt Lake County. Several experiments were performed during this study to try to improve the wind fields, but data limitations prevented further improvements without creating artificial observations. However, the peak secondary PM_{10} concentrations predicted by the model are only slightly lower than those observed at the AM and N2 sites, which indicates the model is doing well and predicting secondary PM_{10} formation.

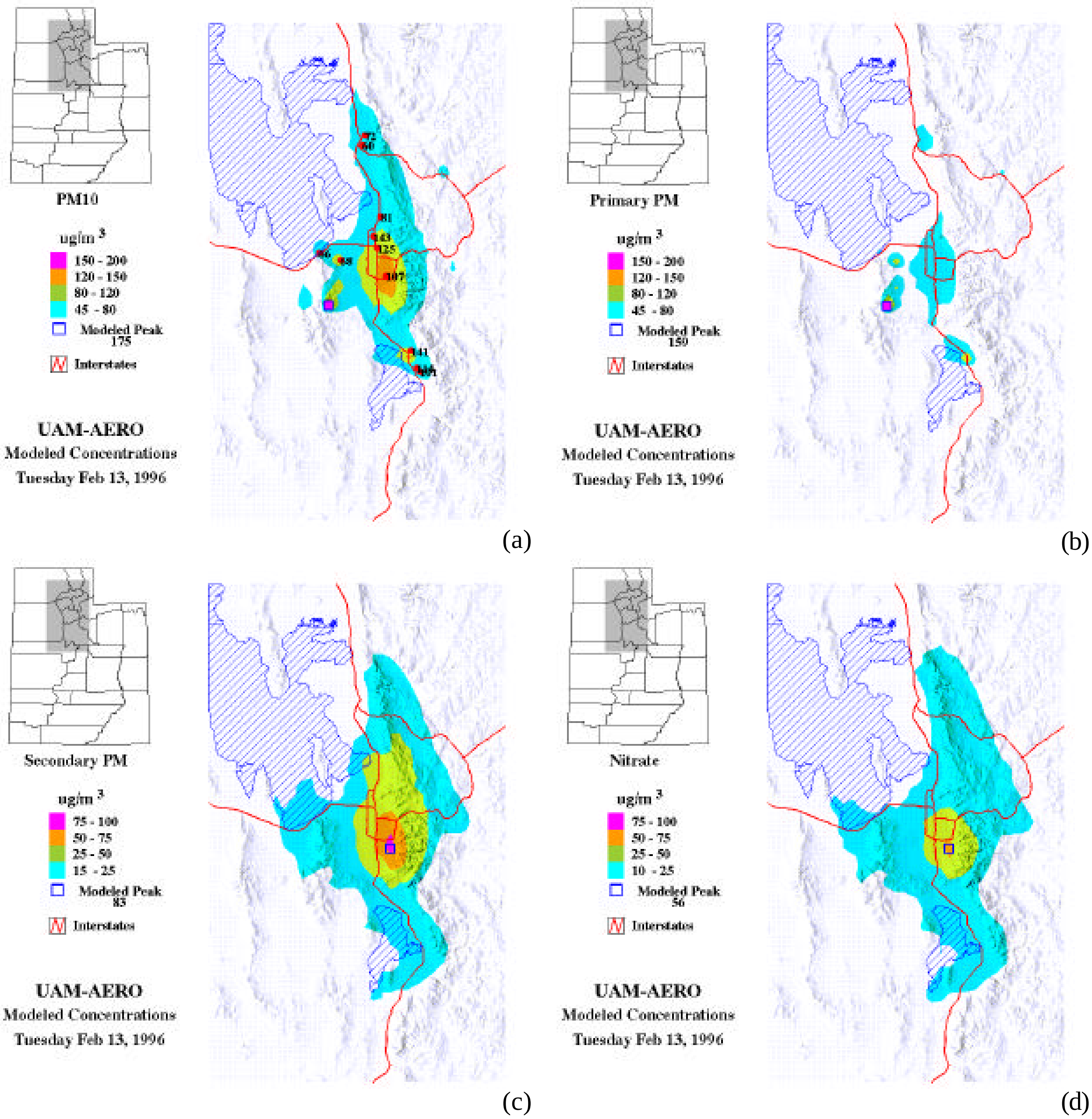


Figure 6-3. 24-hr average predicted and observed total PM_{10} (a), primary PM_{10} (b), secondary PM_{10} (c), and nitrate PM_{10} (d) for February 13, 1996

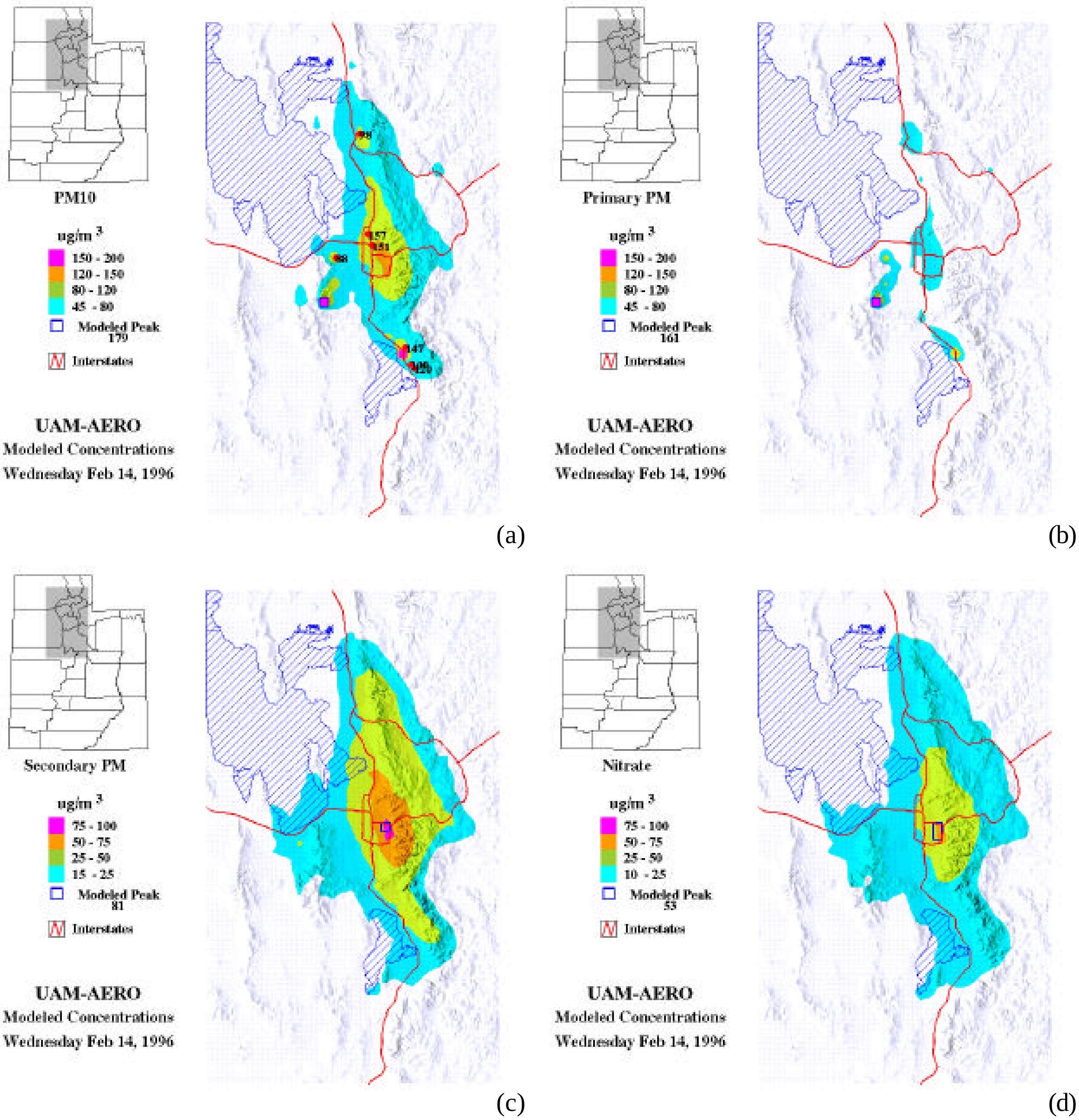


Figure 6-4. 24-hr average predicted and observed total PM_{10} (a), primary PM_{10} (b), secondary PM_{10} (c), and nitrate PM_{10} (d) for February 14, 1996

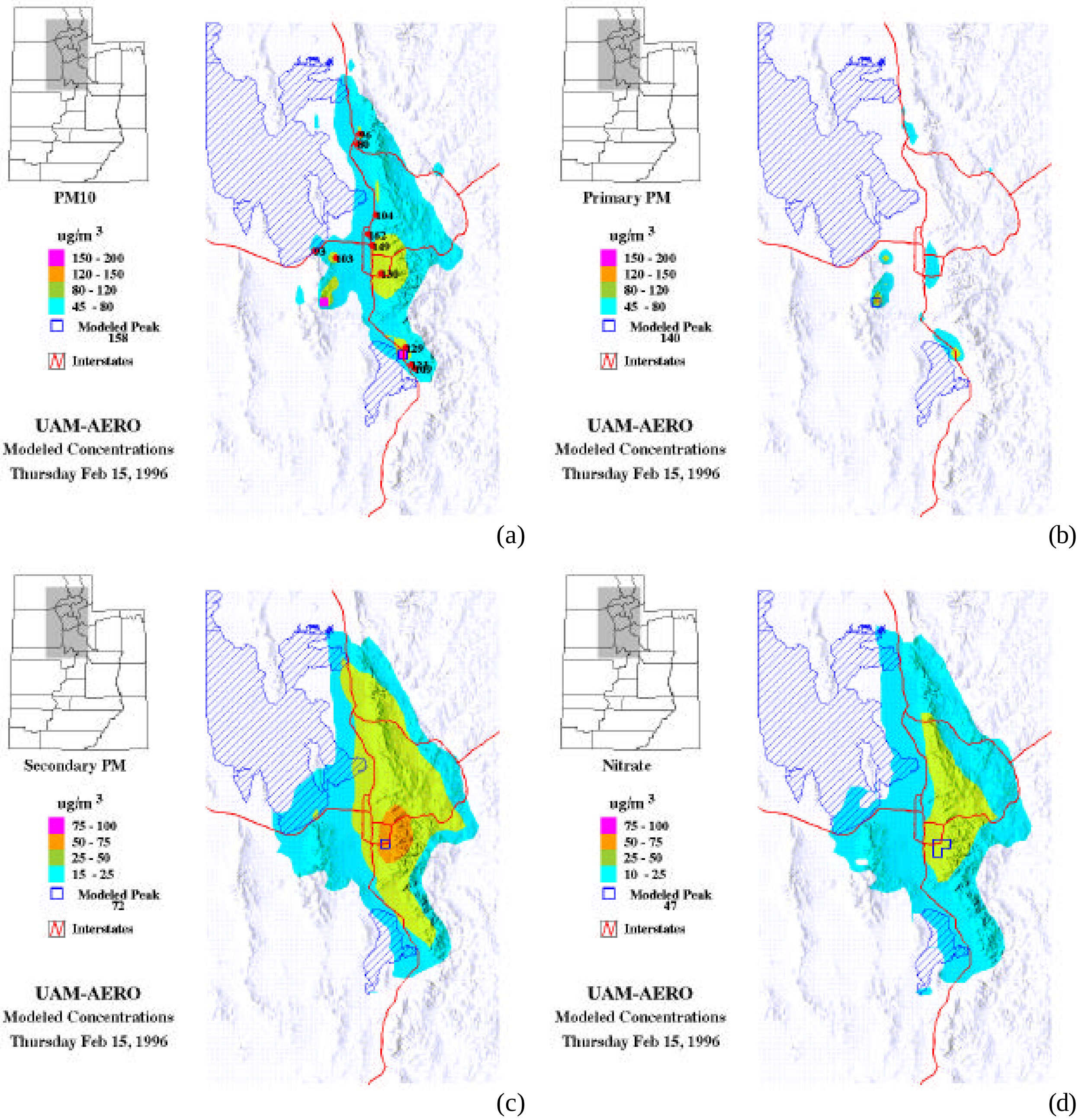
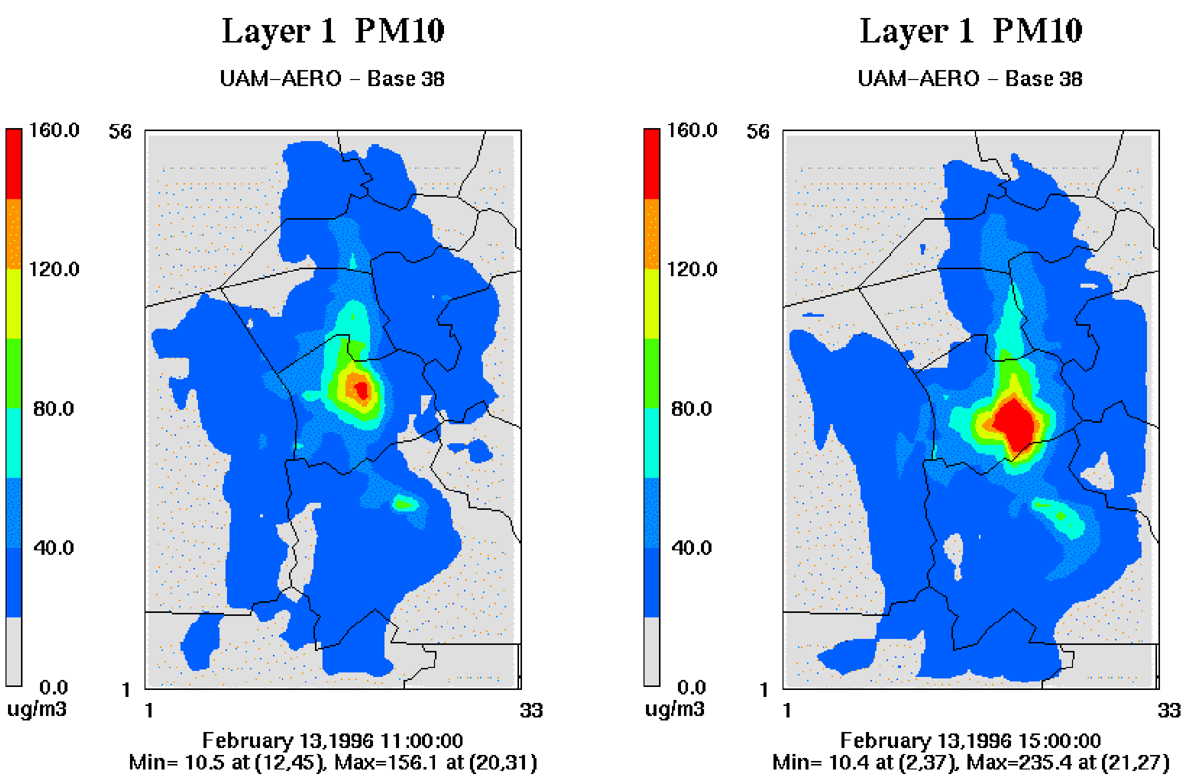


Figure 6-5. 24-hr average predicted and observed total PM_{10} (a), primary PM_{10} (b), secondary PM_{10} (c), and nitrate PM_{10} (d) for February 15, 1996

The spatial bias in the peak PM_{10} concentrations was also seen in the hourly predictions and observations. In **Figures 6-6 through 6-8** the predicted concentrations at the time of the observed peak at the AM site, and the time of the domain-wide predic ted daytime peak, are shown for February 13, 1996 through February 15, 1996 respectively. The hourly TEOM observations at the AM site were used to identify the peak observed time as they were the only TEOM data available to Salt Lake County during the episode. The observations indicate that the peak hourly concentration occurred from 1100 MST to 1200 MST on each of the three days. At the time of the observed peak, the predicted peak is very near the AM site. However, the daytime peak is predicted by UAM-AERO to occur between 1500 MST and 1700 MST at a location further south and east of the AM site.



(a) (b)

Figure 6-6. Predicted PM_{10} concentrations on February 13, 1996 at the time of the (a) observed peak at the AM site and (b) predicted daytime peak in the domain

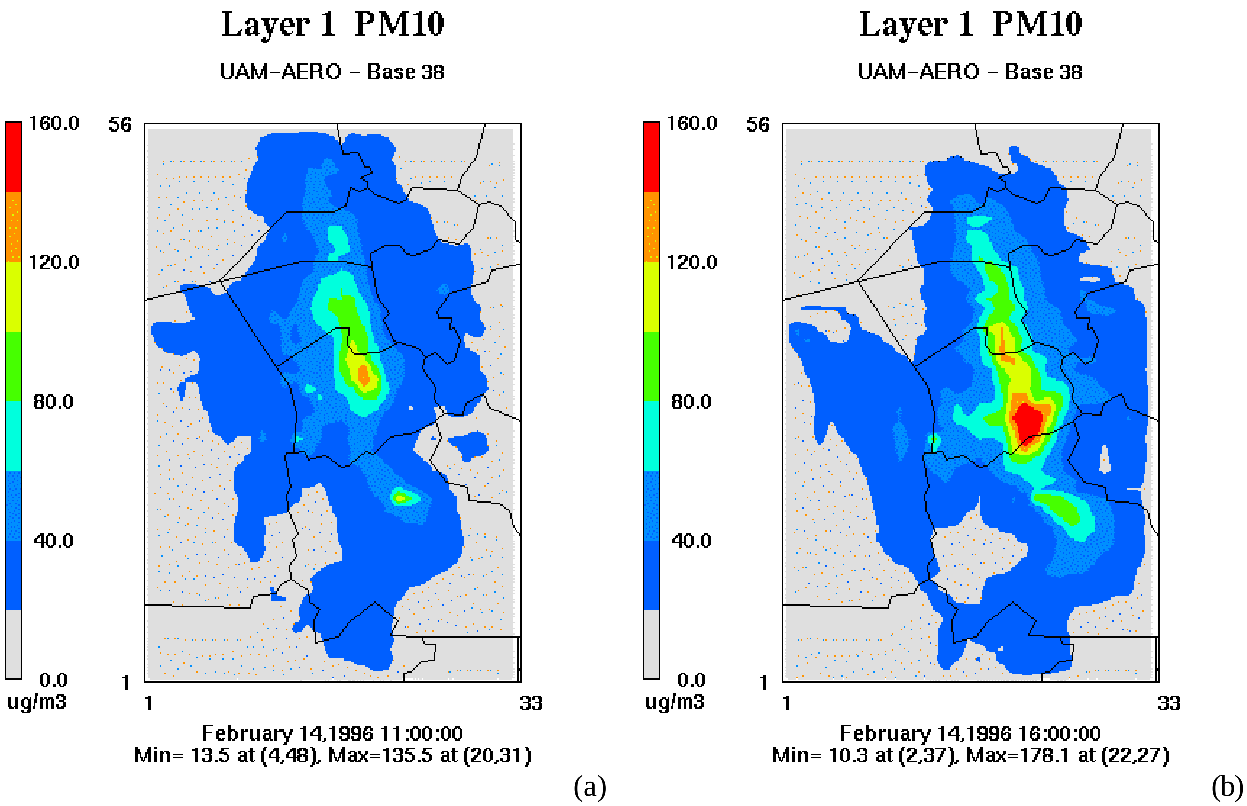
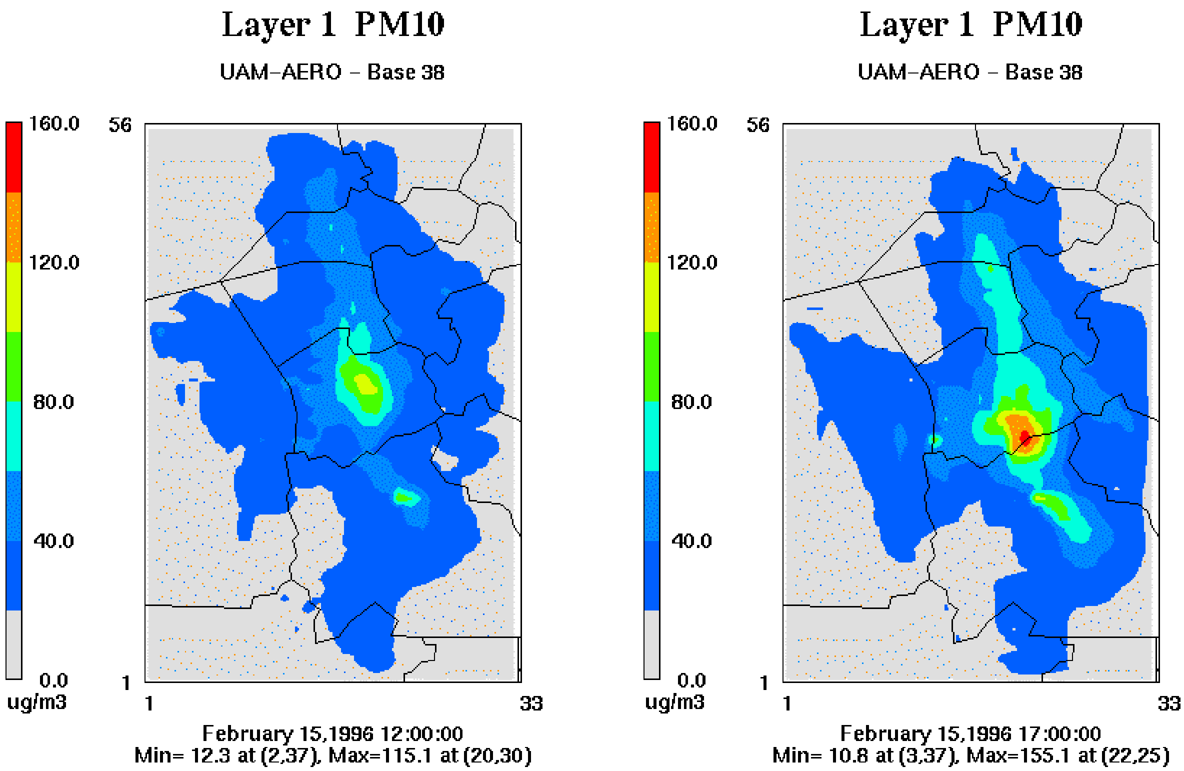


Figure 6-7. Predicted PM_{10} concentrations on February 14, 1996 at the time of the (a) observed peak at the AM site and (b) predicted daytime peak in the domain



(a) (b)

Figure 6-8. Predicted PM_{10} concentrations on February 15, 1996 at the time of the (a) observed peak at the AM site and (b) predicted daytime peak in the domain

6.5.4 Times Series

In this section the hourly PM_{10} mass concentrations are compared with hourly TEOM observations at the AM, LN, and OG sites. While the TEOM instrument was designed to measure $PM_{2.5}$, the AMC staff performed a correlation analysis between PM_{10} and $PM_{2.5}$ and estimated the hourly PM_{10} concentrations based on their analysis. Those estimated PM_{10} concentrations are used in this comparison. Predicted concentrations at the site were estimated by performing bilinear interpolation of values from the four closest model grid cell centers to the sites. In **Figure 6-9** it can be seen that cells 1, 2, 4, and 5 are the closest to site "S" and were used in the interpolation. Additionally, it is useful to depict the local gradients in predicted concentrations to assist in interpreting the model-observation comparisons. To do this, the minimum and maximum concentrations within the cell containing the site, and the eight adjacent cells, were determined. These maximum and minimum concentrations are shown in the following time series plots as dashed lines. For each of the sites total predicted and observed PM_{10} mass concentrations are compared. While hourly speciated data were not available, hourly predicted OTR.1, NO3.1, and SO4.1 are also shown in the plots.

1	2	3
4	S 5	6
7	8	9

Figure 6-9. Grid cells used in the interpolation of concentrations to site "S" (1, 2, 4, and 5) and calculation of 9-cell maximum and minimum concentrations (1 – 9)

At the AM site (**Figure 6-10**) the observations consistently indicated midday peaks. The predictions also show midday peaks but the concentrations are significantly lower. The predicted time series appears to drop off as the peak is advected to the south and east as shown in the previous spatial plots. The predicted concentrations are dominated by the OTR.1 and NO3.1 components, with NO3.1 becoming dominant later in the episode. This predicted contribution from NO3.1 is consistent with speciated samples taken during the episode. The predictions also show two distinct peaks each day, one earlier in the morning and one at midday. Animations of the model results indicate that the first peak is associated with mass re-circulated into the area from the prior day while the second peak is associated with new secondary PM_{10} formation. SO4.1 predictions at the AM site exhibit dual peaks, one at night and one midday. The midday peak is consistent with known daytime SO4.1 formation processes. The nighttime peak could be associated with either re-circulation of SO4.1 mass or known nighttime formation processes. Because of the relatively low sulfate concentrations predicted and the magnitude of the nighttime sulfate peak, it is likely that the nighttime peak is new sulfate formation under foggy conditions.

At the LN site (**Figure 6-11**) the observations consistently showed peaks in the evening hours. The predictions also have evening and nighttime peaks but they are less well-defined than the observed peaks. Strong concentration gradients near the site (see the maximum and minimum traces), may explain these differences. This site is dominated by primary PM_{10} (OTR.1) in both observations and predictions.

At the OG site (**Figure 6-12**) the observations were similar to LN having nighttime peaks but also showed a secondary midday peak. The model predictions are also similar to those at LN but with more NO3.1 evident. Overall, the model does a reasonable job at replicating the diurnal variations at OG but under-predicts mass.

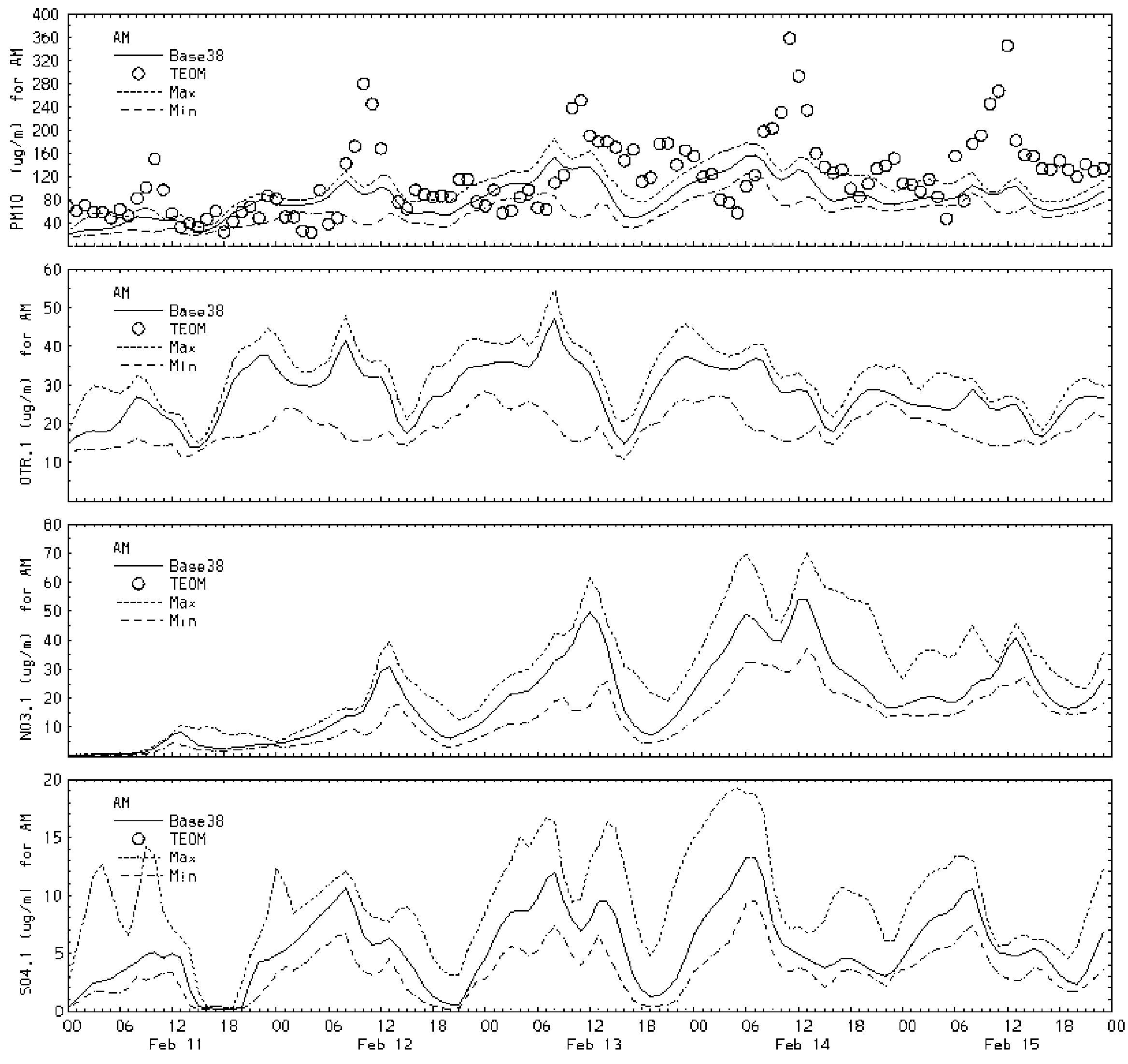


Figure 6-10. Time-series of observed hourly PM_{10}, predicted PM_{10}, and the predicted other OTR.1, NO3.1 and SO4.1 components of PM_{10} for AM

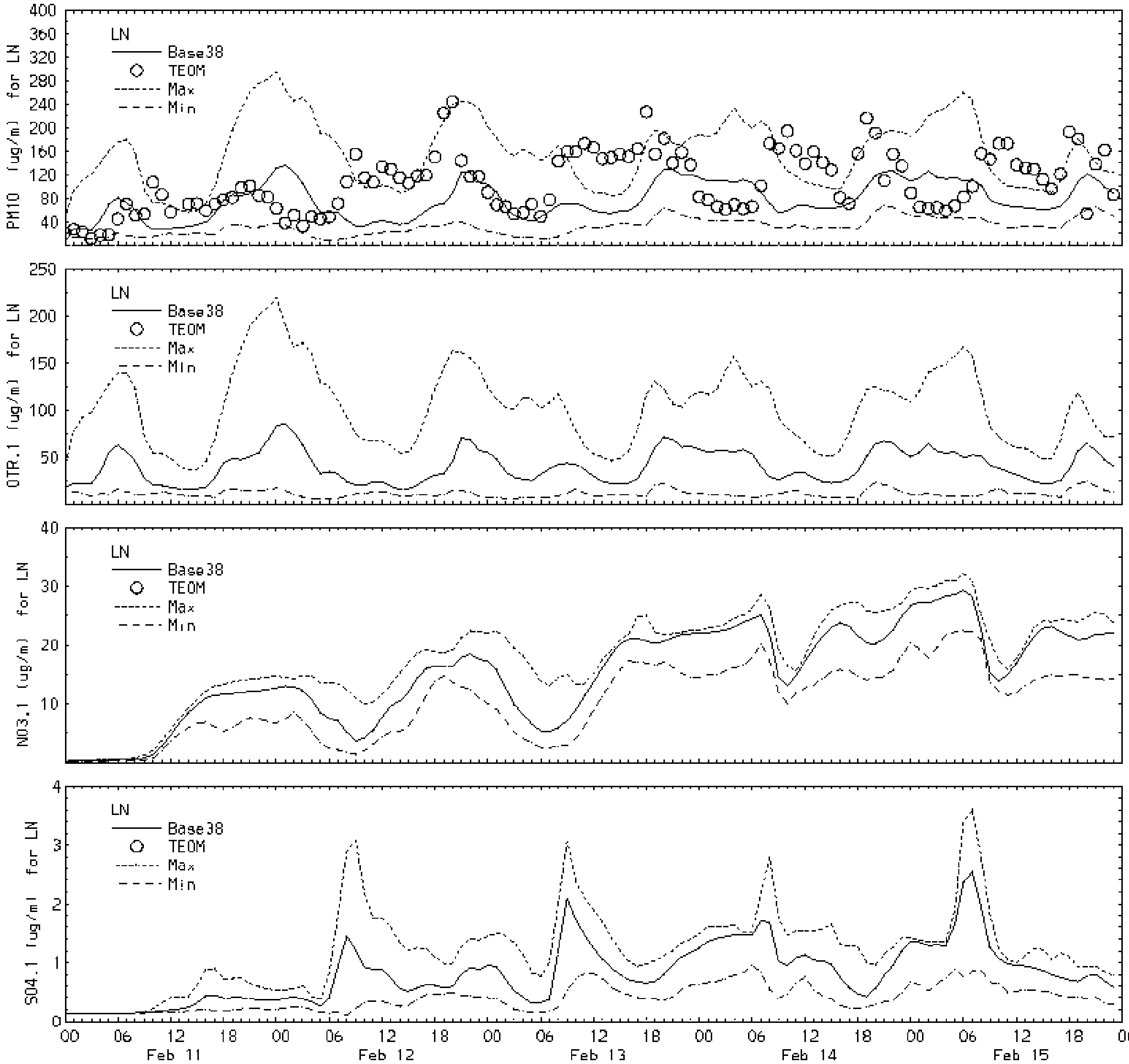


Figure 6-11. Time-series of observed hourly PM_{10}, predicted PM_{10}, and the predicted other OTR.1, NO3.1 and SO4.1 components of PM_{10} for LN

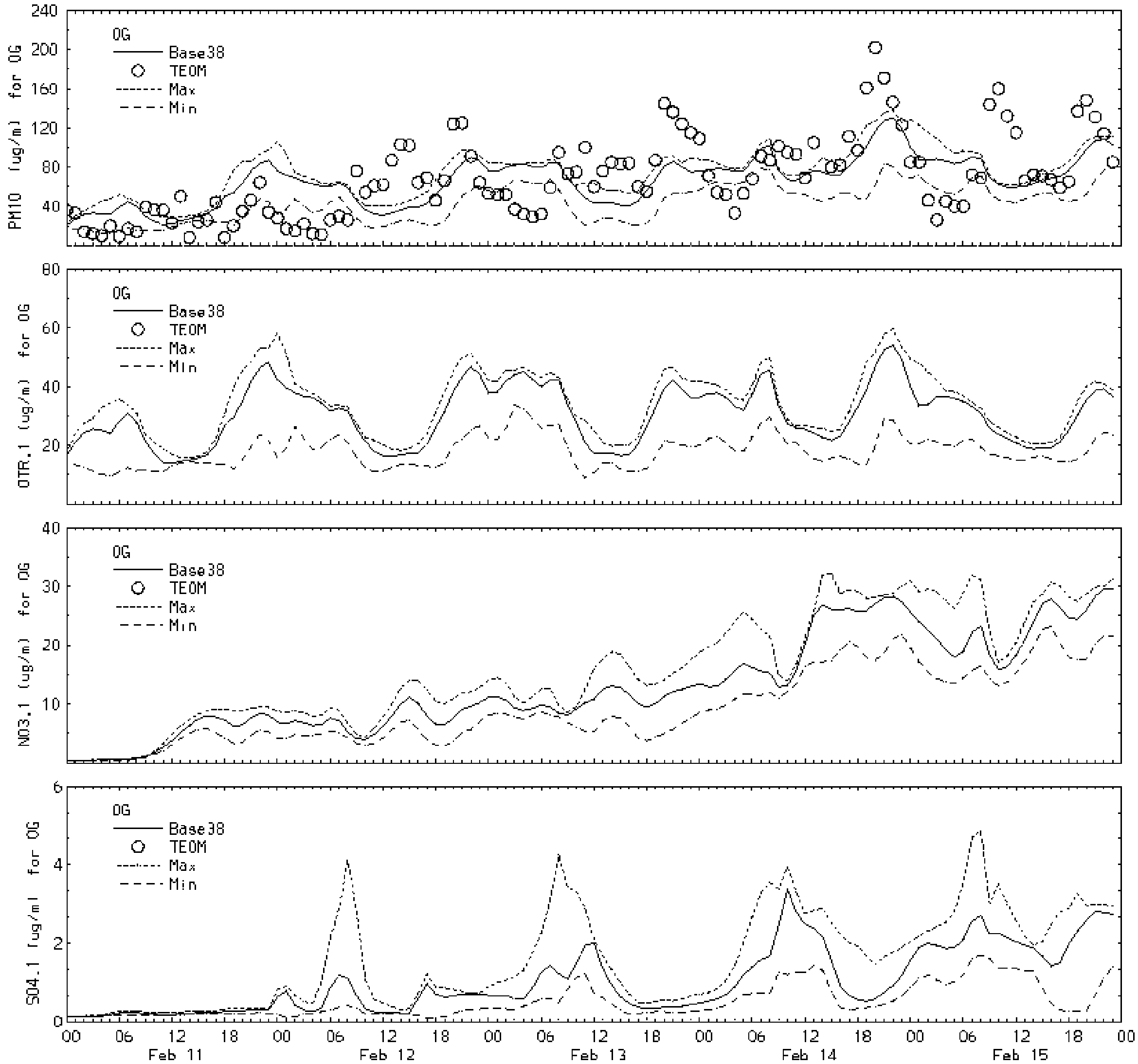


Figure 6-12. Time series of observed hourly PM_{10}, predicted PM_{10}, and the predicted OTR.1, NO3.1, and SO4.1 components of PM_{10} for OG

Figures 6-13 and 6-14 show time series comparisons of predicted and observed CO concentrations. The predicted concentrations were generally consistent with the magnitude and diurnal variations of observed concentrations except for a few midmorning hours where the model did not predict the observed peaks. Because the times of these peaks coincide with emission peaks, the under prediction during these periods were likely due to over prediction of mixing depth growth during this transition period.

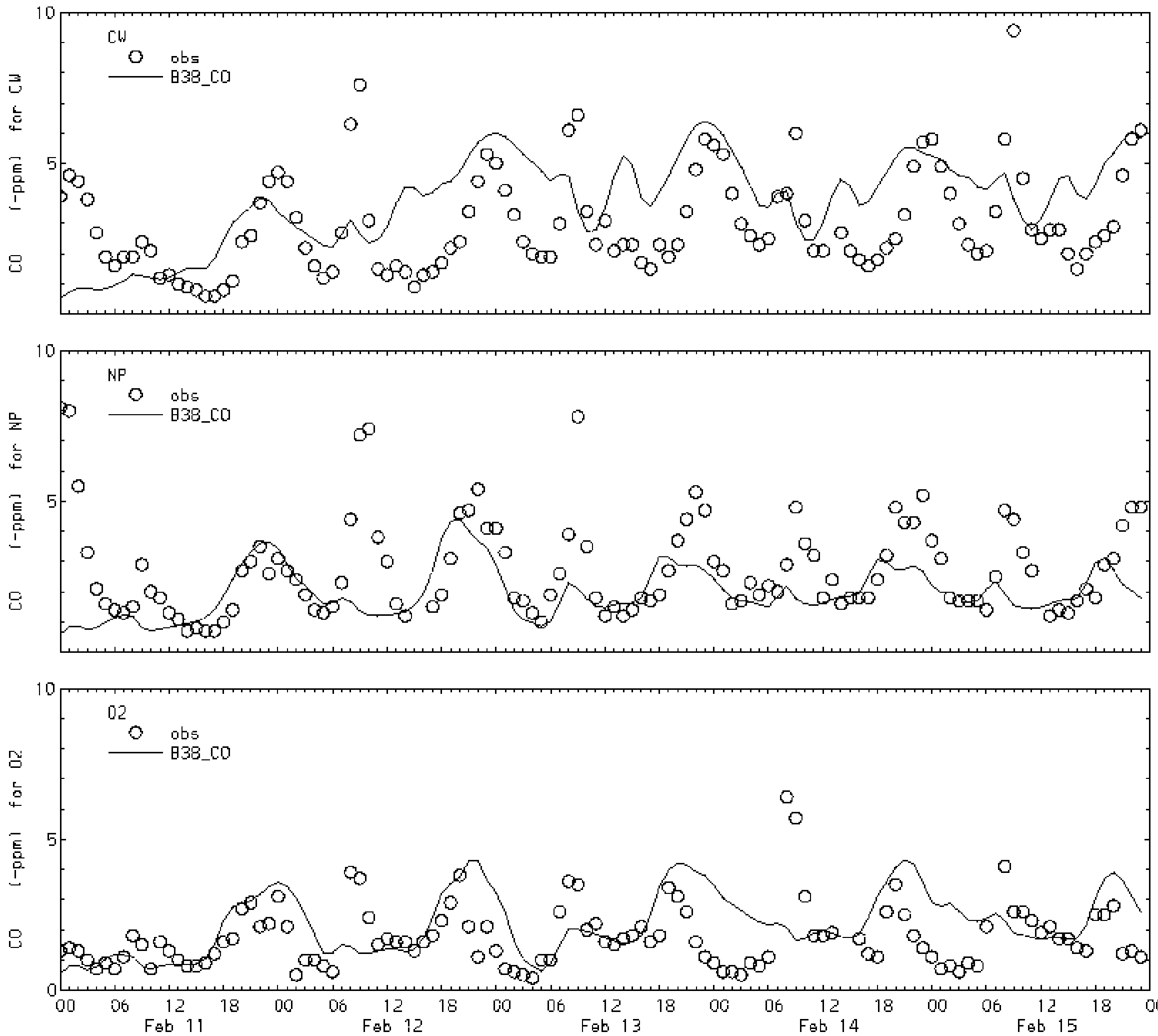


Figure 6-13. Predicted and observed CO concentrations at CW, NP, and O2

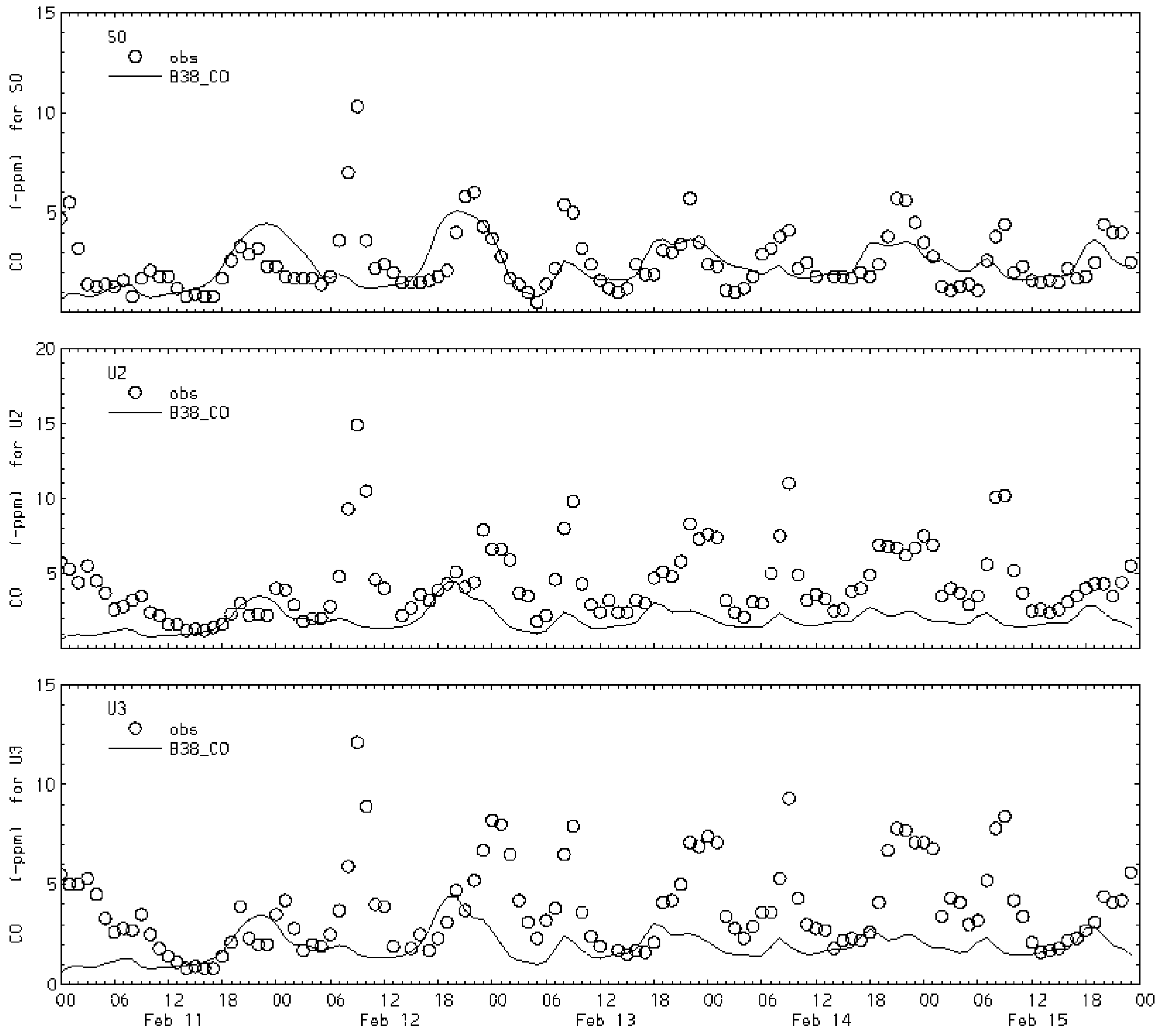


Figure 6-14. Predicted and observed CO concentrations at SO, U2, and U3

6.6 Sensitivity Analysis

6.6.1 Introduction

While the performance described in this section is for base case 38 (B38), sensitivity simulations were performed on base case 34 (B34). The only differences between B38 and B34 are minor emission inventory changes. Therefore, the modeling system's sensitivity to B38 will be nearly identical to that shown for B34.

Table 6-17. Summary of UAM-AERO Sensitivity Simulations

Case	Emissions	Meteorology	Initial, Boundary Conditions	Results
b34s2			Zero Boundary Conditions	Decreased PM_{10} on boundary and some slight increases in PM_{10} just inside the boundary
b34s3	Zero Anthropogenic Emissions			Large decreases in PM_{10}
b34s4	Zero PM10 Emissions			Significant decreases in PM_{10}
b34s5	Double PM10 Emissions			Large increases in PM_{10} (3-40+ µg/m^3)
b34s6	Zero NH3 Emissions			Decreased PM_{10}
b34s7	Double NH3 Emissions			Little change; the system does not appear to be ammonia limited in most areas.
b34s8	50% NOx Emissions			Decreases in PM_{10} in portions of central Salt Lake City, increases (3-10 µg/m^3) on the fringes of the urban core, and decreased PM_{10} in outlying areas (3-10 µg/m^3).
b34s9	50% VOC Emissions			Decreased PM_{10} in urban core due to reduction in VOC (3-20 µg/m^3)
b34s10	50% NOx and VOC Emissions			Large scale reduction (3-30+ µg/m^3) in PM_{10} with localized small disbenefits
b34s11	Zero mobile emissions			Large scale reduction (3-40+ µg/m^3) in PM_{10} with localized small disbenefits over Utah Lake.
b34s12	Double mobile emissions			Significant increases modeled PM_{10} all along the Wasatch Front (greater than 40 µg/m^3 in most of this region)
b34s13	Zero surface depositions			Domain-wide increases in PM_{10} with greater than 40 µg/m^3 increases in areas with high concentrations
b34s14		Wind speeds increased by 25%		Significant (3-40+ µg/m^3) reductions in PM_{10} that are widespread
b34s15		Wind speeds decreased by 25%		Small decreases in PM_{10} in central Salt Lake City (generally 3-30 µg/m^3) and increases in PM_{10} in outlying areas (3-10 µg/m^3)
b34s16		Diffusion break increased by 25%		Decrease of PM10 in central Salt Lake City (3-20 µg/m^3) due to higher diffbreak.
b34s17		Diffusion break decreased by 25%		Increase in PM10 (3-30 µg/m^3) due to lower diffbreak.
b34s18		Zero fog and haze		Large decreases in PM10 (3-40+ µg/m^3) domain wide due to removal of all fog and haze.
b34s19		All fog		Moderate decrease in PM10 (3-20 µg/m^3) due to the entire domain being covered with fog
b34s20	50% NH3 reduction			Moderate decrease (< 20 µg/m^3) in PM_{10}

6.6.2 Results

In this section the results of each of the sensitivity simulations are summarized in a plot of the differences between the sensitivity simulation and the base case. The values presented are the 24-hr average PM_{10} concentration for the sensitivity minus those for the base case on February 13, 1996. February 13 was used because it was the day with the highest predicted PM_{10} concentrations. Thus, positive values indicate increases in PM_{10} for the sensitivity and negative values indicate decreases. Table 6-17 indicates the model run name.

The zero boundary condition sensitivity simulation (b34s2, **Figure 6-15**) resulted in decreased PM_{10} in the boundary cells. The magnitude of the change is in the range of the original PM_{10} mass specified for the boundary (15 µg/m^3) and is as expected. Slight increases in PM_{10} just inside the boundary are also noted. In the interior of the modeling domain, there is effectively no impact, which indicates the modeling domain is sufficiently large for this episode and that the predictions in Salt Lake and Utah counties are not affected the boundaries.

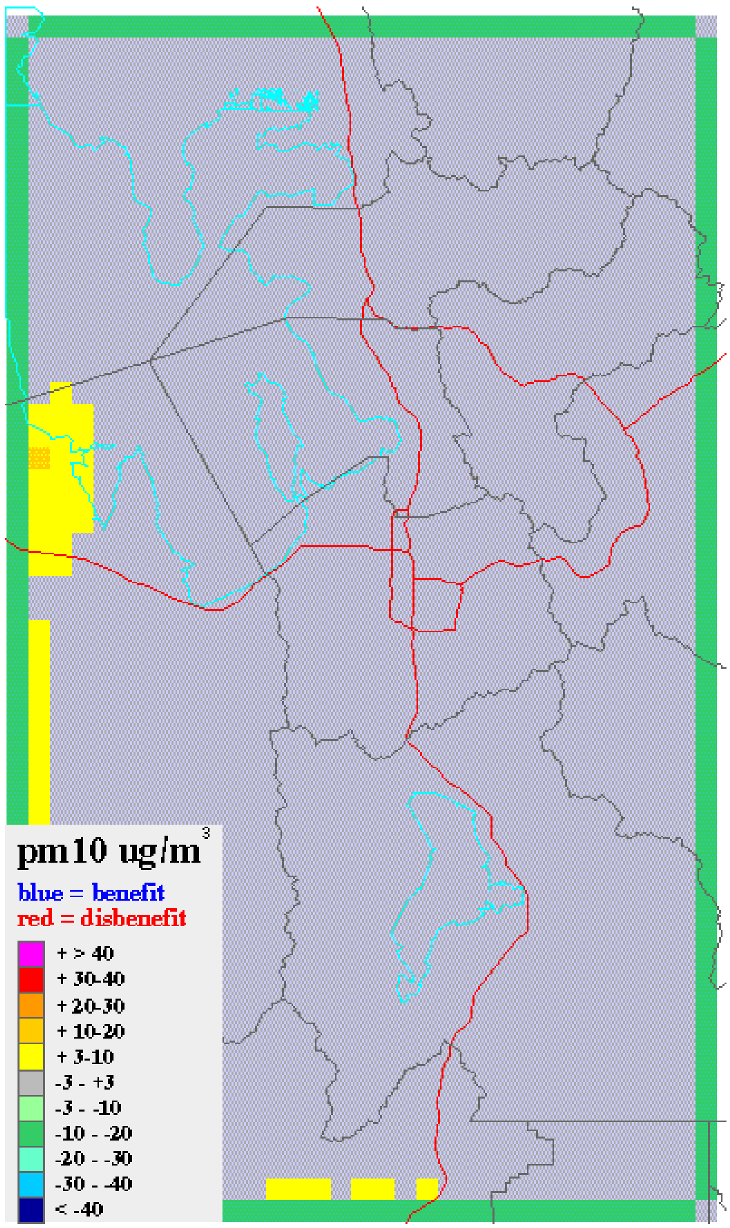


Figure 6-15. Sensitivity 2 (b34s2) – Change in daily average PM_{10} on February 13, 1996, due to boundary conditions set to zero

As expected, the elimination of anthropogenic emissions (b34s3, **Figure 6-16)** resulted in large, domain-wide, decreases in total PM_{10}. The greatest impact is in the Wasatch Front region, where the largest emissions sources exist.

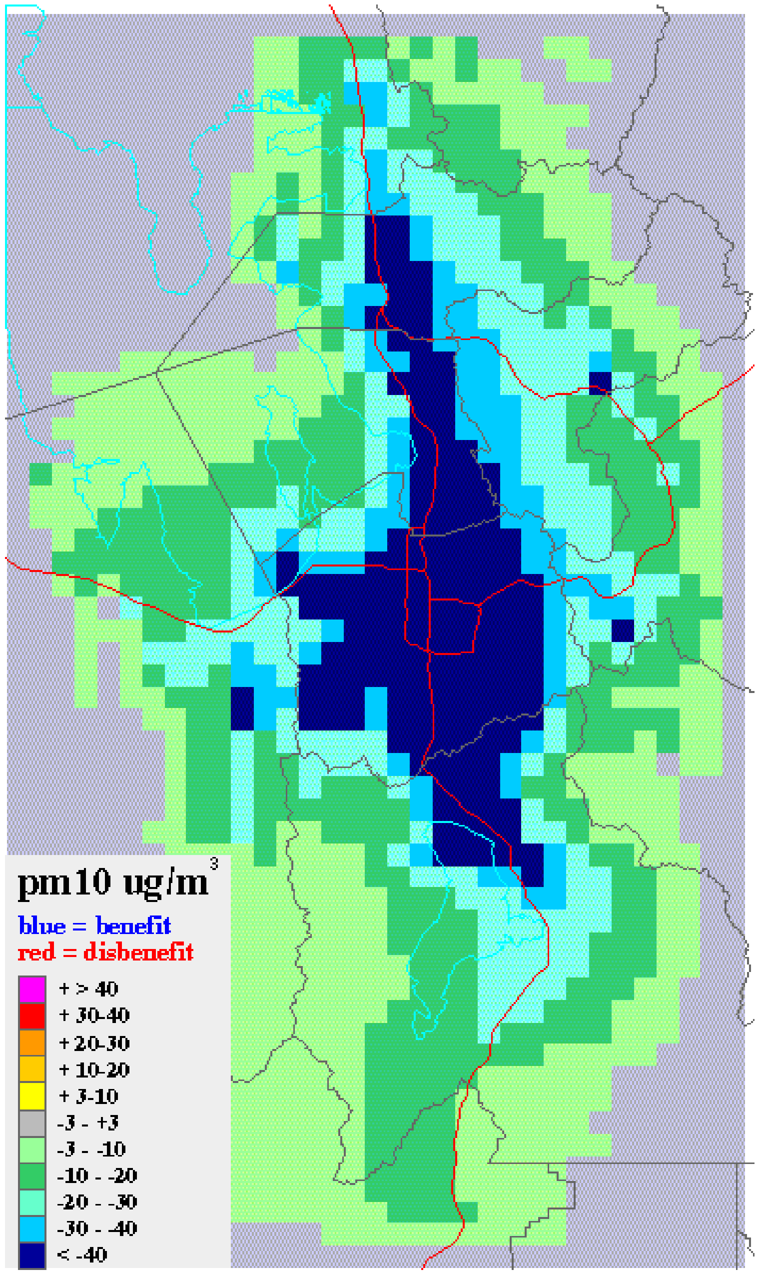


Figure 6-16. Sensitivity 3 (b34s3) – Change in daily average PM_{10} on February 13, 1996, due to zero anthropogenic emissions

The effect of eliminating primary PM_{10} emissions is shown in **Figure 6-17** (b34s4). There is a general reduction of modeled PM_{10} in areas with PM_{10} emissions as expected. When compared to Sensitivity 3 (b34s3, Figure 6-16), the relative contributions of primary emissions and secondary aerosol precursors can be seen.

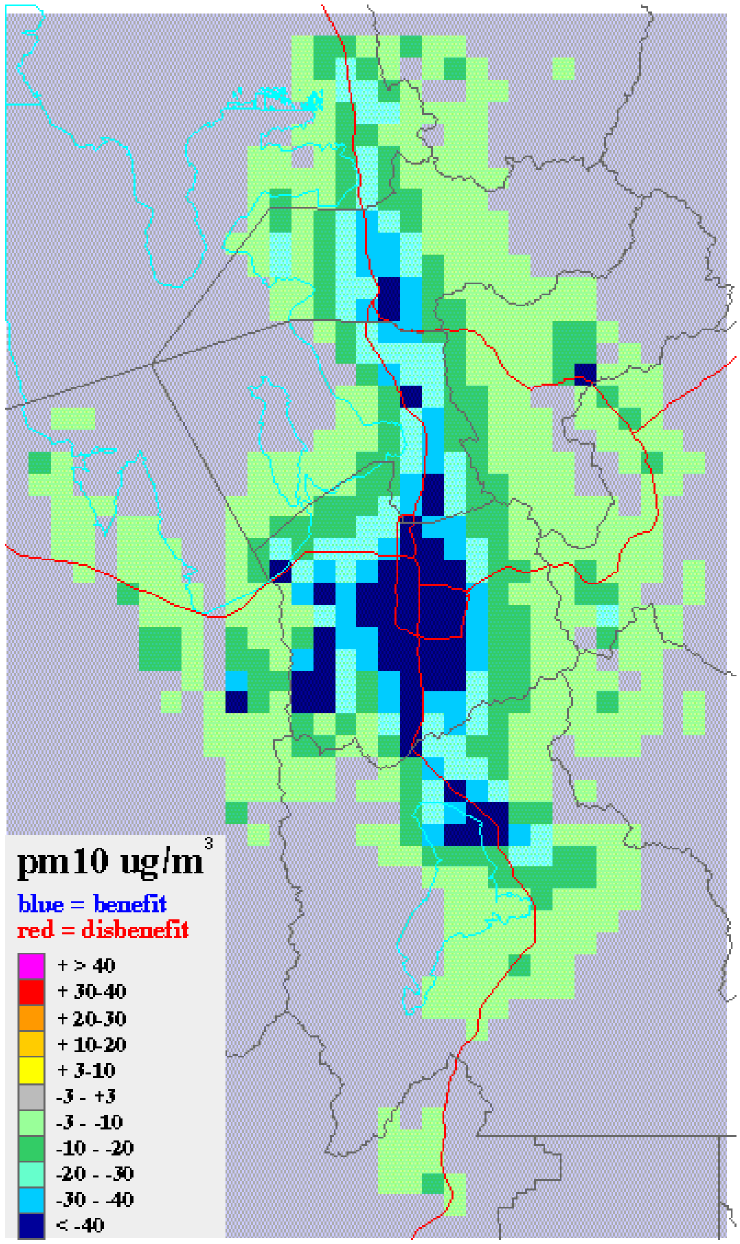


Figure 6-17. Sensitivity 4 (b34s4) – Change in daily average PM_{10} on February 13, 1996, due to zero PM_{10} emissions

Doubling PM_{10} emissions significantly increases modeled PM_{10} mass concentrations as shown in **Figure 6-18** (b34s5). The largest increases occur in areas with the largest PM_{10} emissions as expected.

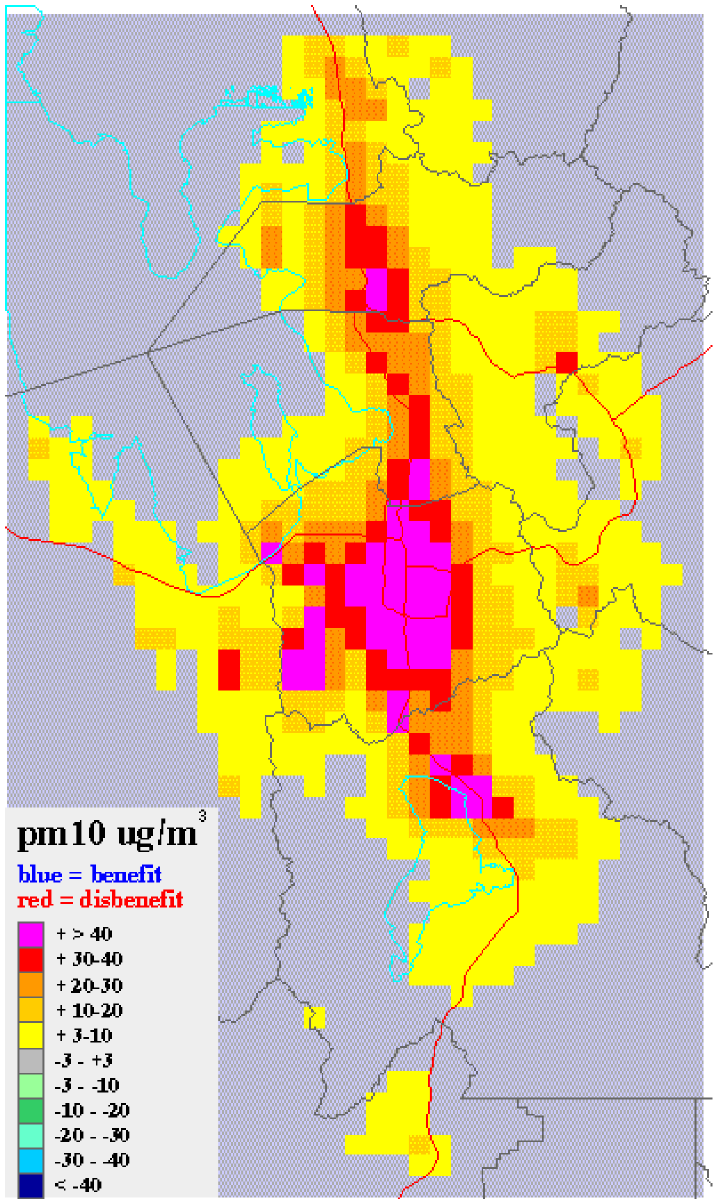


Figure 6-18. Sensitivity 5 (b34s5) – Change in daily average PM_{10} on February 13, 1996, due to double PM_{10} emissions

Eliminating ammonia emissions results in a significant decrease in PM_{10} as shown in **Figure 6-19** (b34s6). The largest impacts are in the southeast portion of Salt Lake County where the highest nitrate aerosol concentrations are predicted. This is also an area where anthropogenic emissions are low, and diagnostic simulations indicate that secondary aerosol formation may be ammonia-limited.

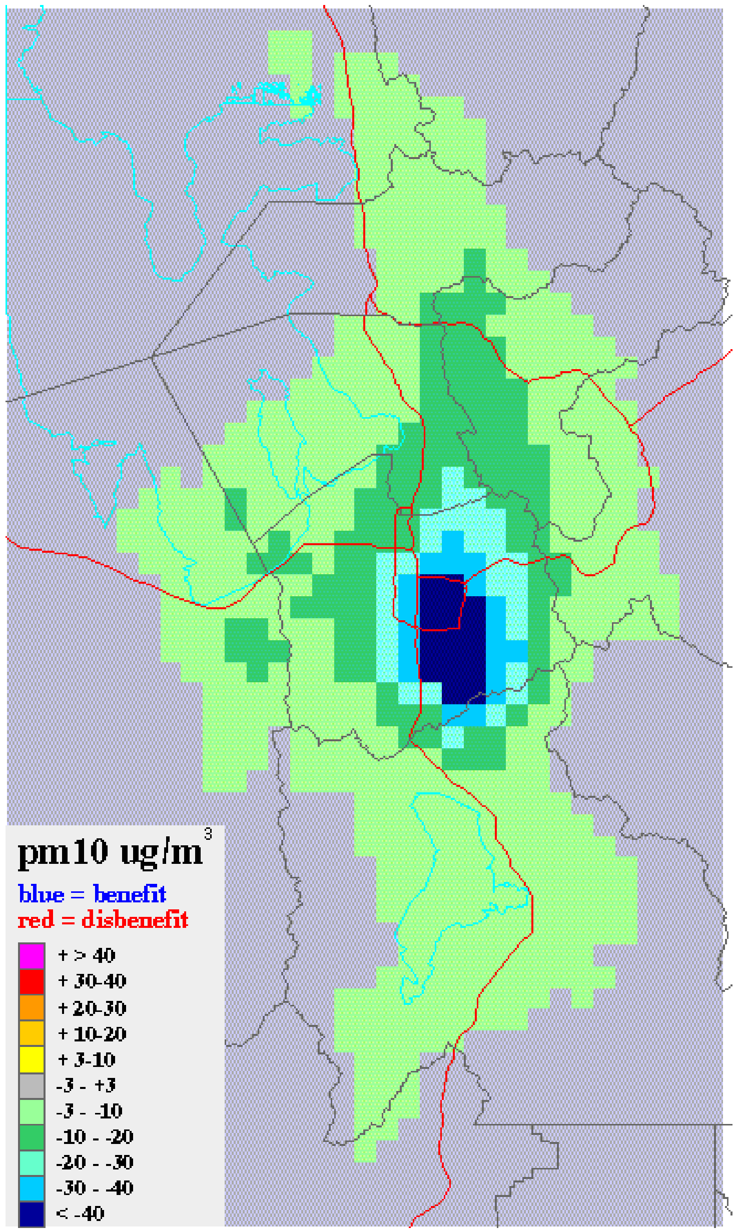


Figure 6-19. Sensitivity 6 (b34s6) – Change in daily average PM_{10} on February 13, 1996, due to zero ammonia emissions

In Sensitivity 7 (b34s7, **Figure 6-20**) the doubling of ammonia emissions has almost no impact on modeled PM_{10}. This result indicates that the amount of ammonia emissions in the base case simulation is sufficient to maximize production of secondary aerosols. Further increases in ammonia emissions do not increase secondary aerosol formation, except downwind of the Magnesium Corporation plant near Rowley where conditions may be ammonia-limited.

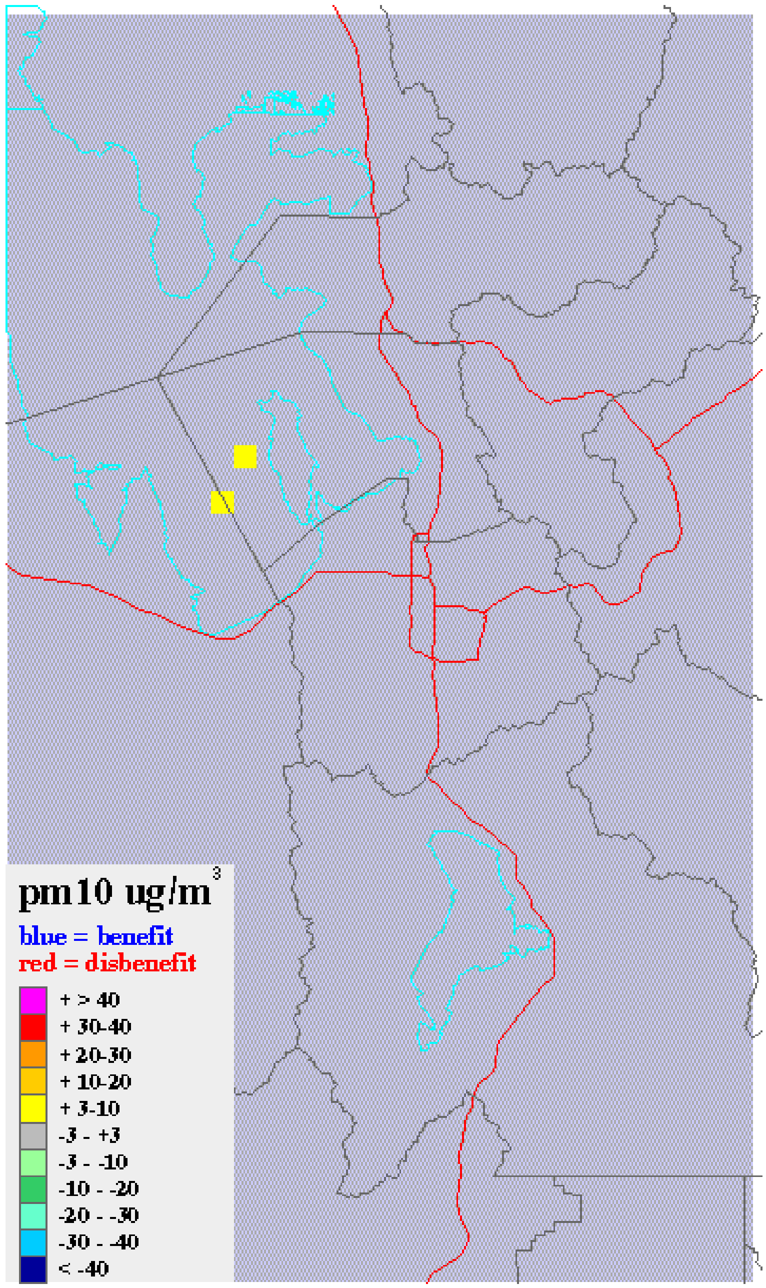


Figure 6-20. Sensitivity 7 (b34s7) – Change in daily average PM_{10} on February 13, 1996, due to doubled ammonia emissions

As shown in **Figure 6-21** (b34s8), the effect of reducing NO_x emissions by 50% is to increase modeled PM_{10} in regions just outside populated areas of the domain and to slightly reduce modeled PM10 in the outlying areas. There are also some modest reductions at the AM and N2 sites where the maximum observed values were reported. The predicted disbenefits associated with NO_x emission reductions is well-understood and is discussed below.

6.6.3 Discussion - NO_x Reduction Disbenefits

The sensitivity simulation (b34s8) of the February 11-15, 1996, PM_{10} episode with 50% reduction of NO_x emissions shows disbenefits in several areas of the domain. Because this model response is counter-intuitive, the following explanation of the disbenefits predicted by UAM-AERO is provided.

A review of the temporal and chemical differences between the base case simulation and Sensitivity 8 (the 50% NO_x reduction simulation) indicates that the disbenefits shown in the 24-hr average PM_{10} concentrations are due to increased nitrate aerosol production at night.

The nitrate aerosol, ammonium nitrate (NH_4NO_3), is formed through a reaction of NH_3 and HNO_3. HNO_3 is formed through the oxidation of NO_2 by an OH radical,

$$OH + NO_2 \xrightarrow{(M)} HNO_3$$

This reaction is about 10 times more rapid than the corresponding OH oxidation of SO_2 and is thus the major route of nitric acid formation in the boundary layer during daylight hours. A second mechanism for nitric acid formation may be important at night. When NO_2 is oxidized by O_3, the nitrate radical (NO_3) is formed,

$$O_3 + NO_2 \rightarrow NO_3 + O_2$$

The nitrate radical is not stable during daylight hours due to photolysis and is not stable in the presence of NO. However at night, under low NO concentrations, the NO_3 decomposition path becomes slow and other NO_3 chemistry can become important, namely the reaction with NO_2 and H_2O or with gaseous aldehydes, forming HNO_3 in both cases.

$$NO_3 + NO_2 \overset{(M)}{\rightleftarrows} N_2O_5$$

$$N_2O_5 + H_2O \rightarrow 2HNO_3$$

When NO_x emissions are reduced as in Sensitivity 8, the concentrations of NO are reduced in the "fringe" areas (where there are no direct emissions) to levels at which this pathway for HNO_3 formation is possible. An examination of nighttime nitrate radical and HNO_3 concentrations in the model output confirms this. Therefore, more nitrate aerosol is produced in these regions.

The chemical processes for these phenomena have been extensively studied in both the ambient atmosphere and in the laboratory. These processes are represented in UAM-AERO, and the model's response is consistent with the observed chemical behavior. In addition, previous simulations with UAM-AERO for southern California showed similar results in rural areas and aloft where NO concentrations were low.

In summary, the reduction of NO_x emissions lowers NO concentrations in areas outside the cities at night. These low NO concentrations allow a nighttime nitric acid formation mechanism to become active, producing additional nitric acid. The additional nitric acid reacts with ammonia to form more ammonium nitrate. It should be noted that there are generally no disbenefits in the highest NO_x emissions areas, where the highest PM_{10} concentrations were observed.

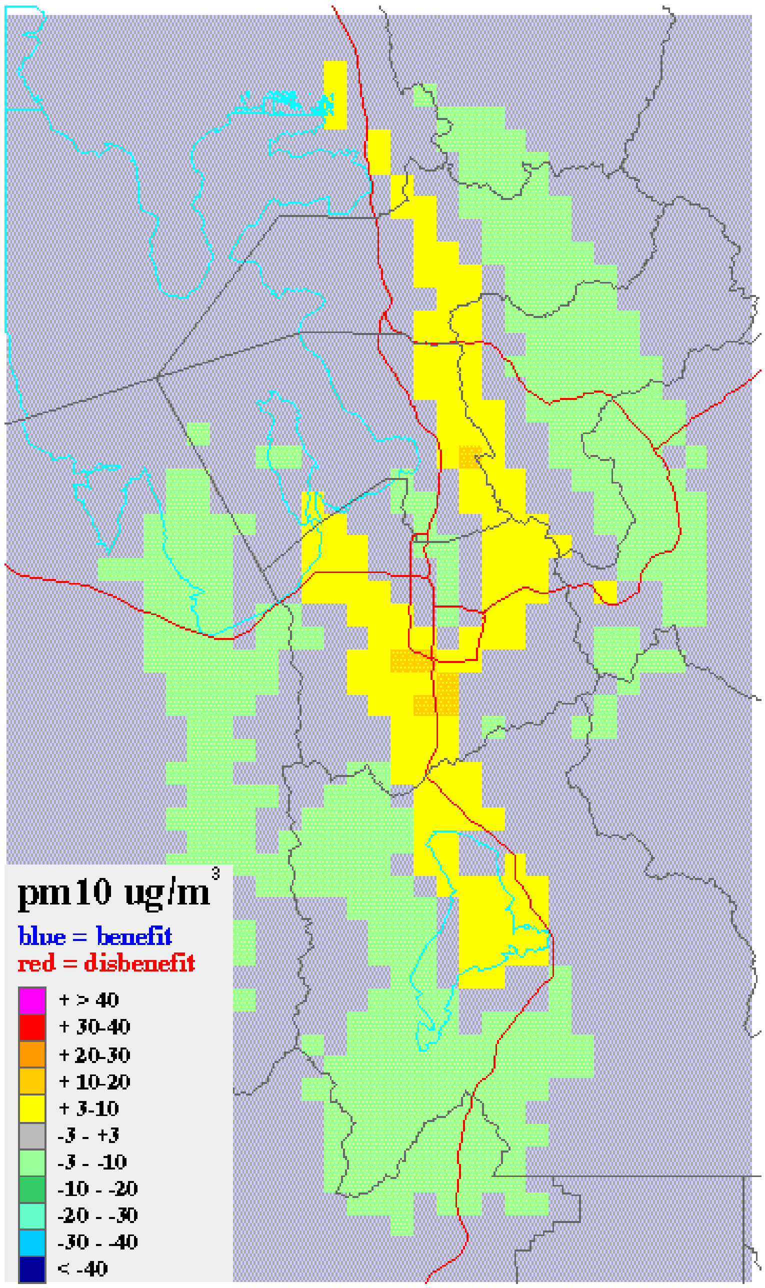


Figure 6-21. Sensitivity 8 (b34s8) – Change in daily average PM_{10} on February 13, 1996, due to 50% reduction in NO_x emissions

Reducing VOC emissions by 50% reduces the modeled PM_{10} concentrations by 10 to 40 µg/m^3 over much of Salt Lake County (b34s9, **Figure 6-22**). The effect is greatest in the southeast portion of Salt Lake County where there is significant production of secondary aerosols. This response demonstrates the significance of VOCs in the photochemistry responsible for secondary aerosol formation. These results, in combination with those for the NO_x reduction sensitivity, suggest that there are more than sufficient NO_x emissions in the region to produce the secondary aerosol concentrations observed, and that the efficiency of secondary aerosol formation in the UAM-AERO simulation is largely controlled by the availability of VOCs.

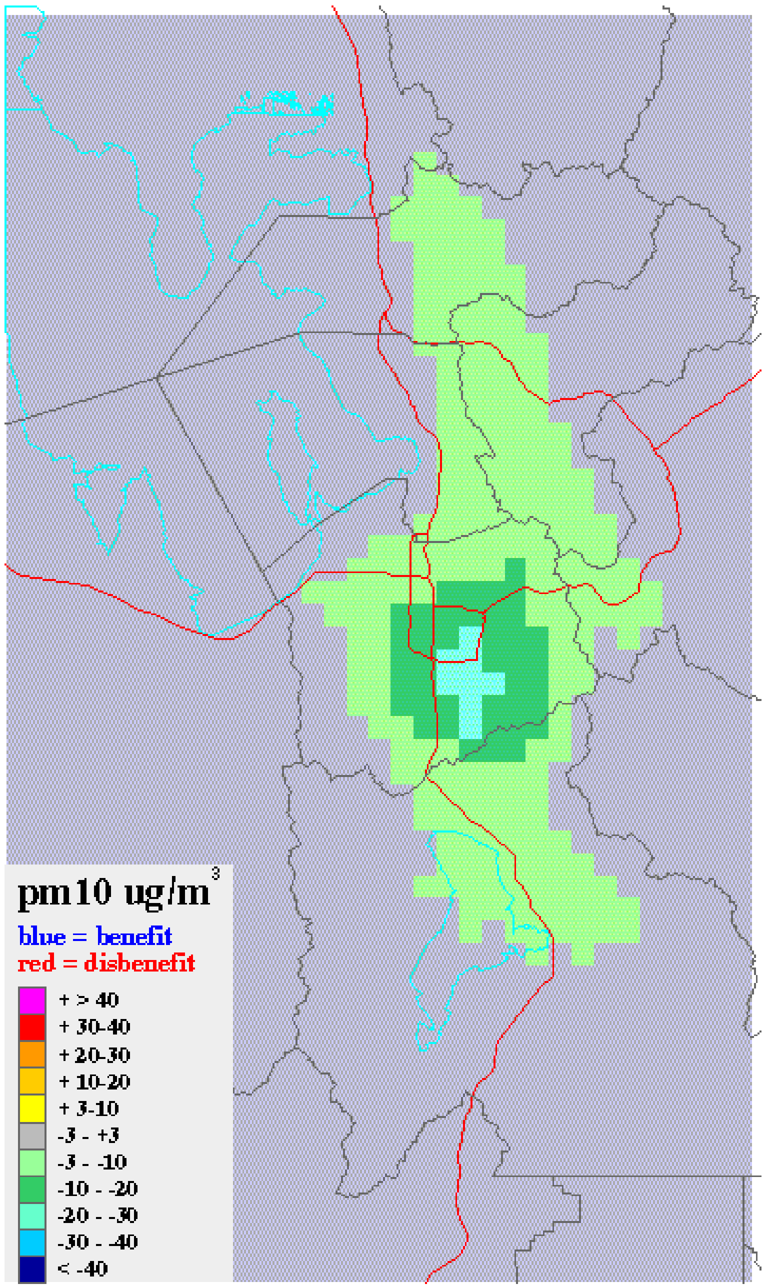


Figure 6-22. Sensitivity 9 (b34s9) – Change in daily average PM_{10} on February 13, 1996, due to a 50% reduction in VOC emissions

The results of reducing both NO_x and VOC emissions by 50% are shown in **Figure 6-23** (b34s10). The reductions in modeled PM_{10} are seen throughout most of the domain with only a few cells (at the south shore of the Great Salt Lake and over Utah Lake) showing increased PM_{10} concentrations. The impact is greatest in the area of highest modeled PM_{10} (southeast Salt Lake County) and reduces PM_{10} by as much as 30 to 40 µg/m^3.

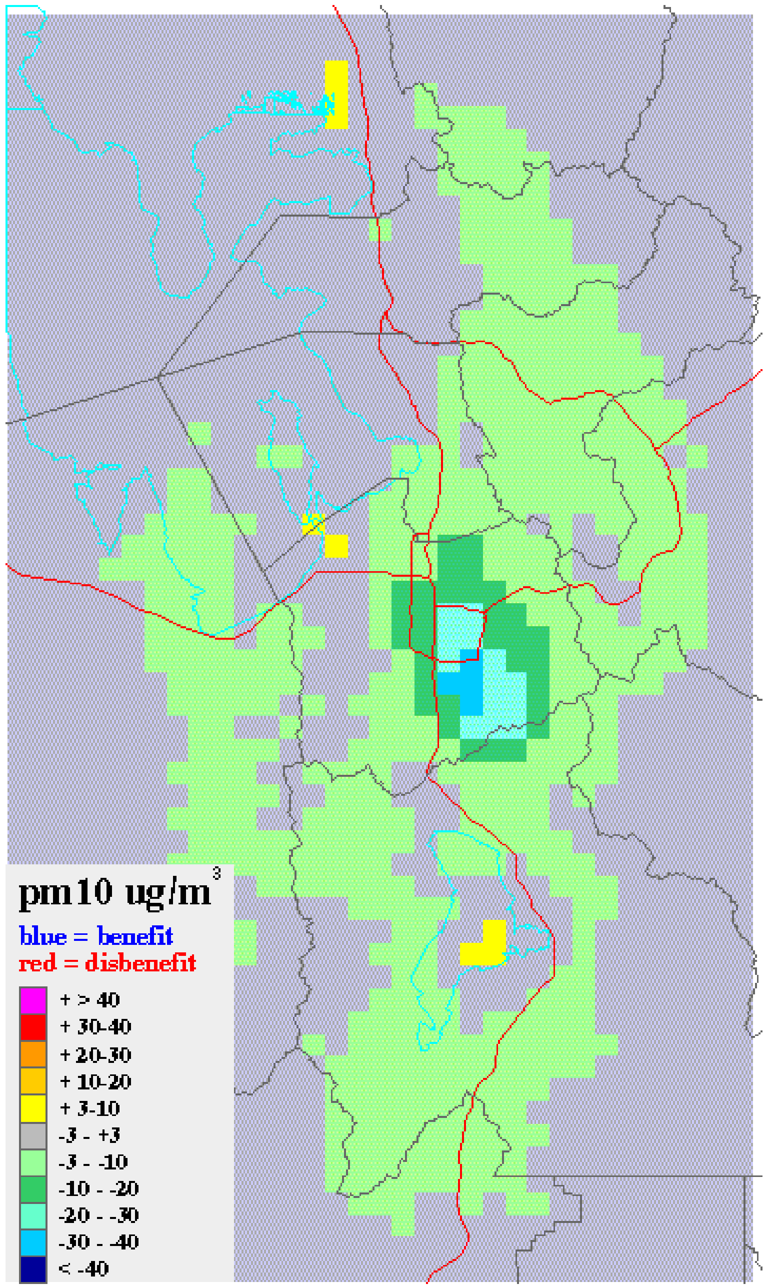


Figure 6-23. Sensitivity 10 (b34s10) – Change in daily average PM_{10} on February 13, 1996 due to a 50% reduction in both NO_x and VOC emissions

Eliminating mobile source emissions from the simulation (b34s11, **Figure 6-24**) results in significant reductions in modeled PM_{10} over the entire populated domain. The most significant impacts are in southeast Salt Lake County. The impact of zero mobile emissions is greater than that for 50% reduction in VOC and NO_x emissions. This result was expected since mobile sources account for a significant portion of collocated NO_x, VOC, and ammonia emissions.

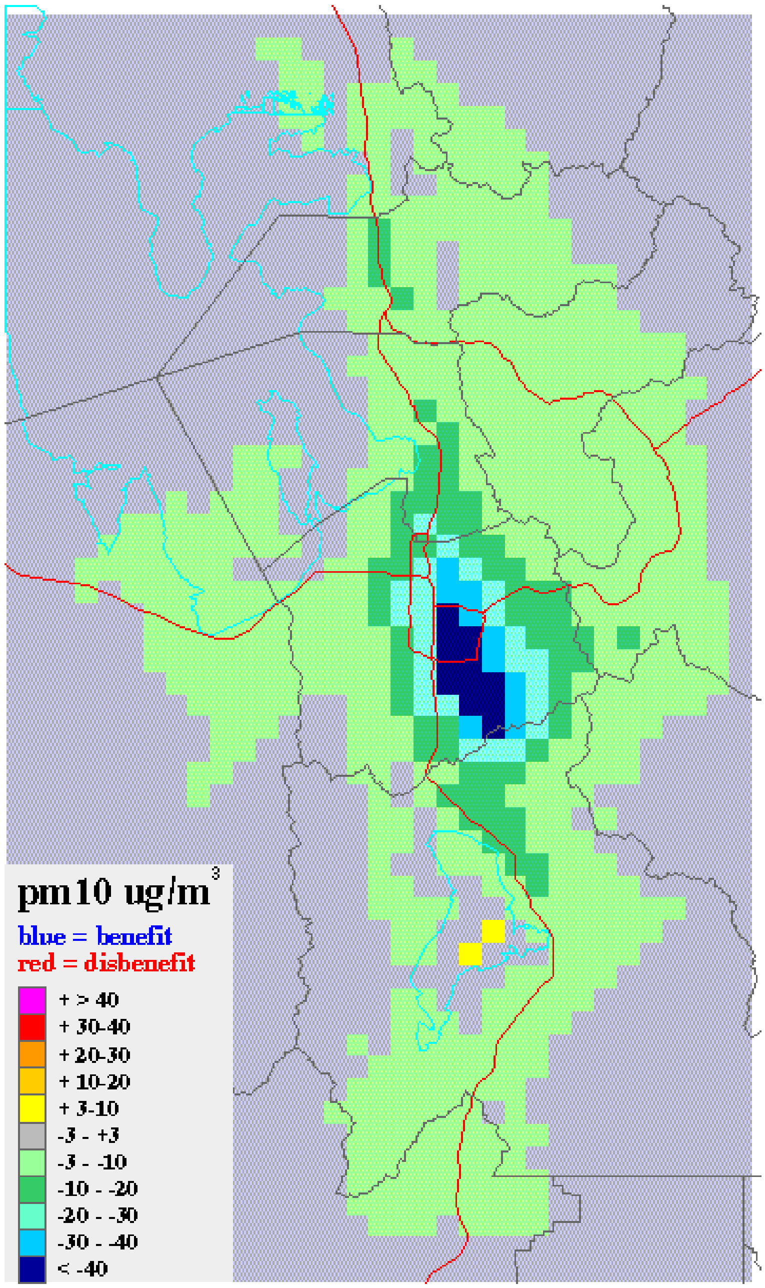


Figure 6-24. Sensitivity 11 (b34s11) – Change in daily average PM_{10} on February 13, 1996, due to zero mobile source emissions

Doubling mobile source emissions greatly increases modeled PM_{10} all along the Wasatch Front (b34s12, **Figure 6-25**). The impact is greater than 40 µg/m^3 over most of this region. This result is consistent with the results from the zero mobile source sensitivity simulation (Sensitivity 11, b34s11) and highlights the role of mobile source emissions in the formation of aerosols in the region.

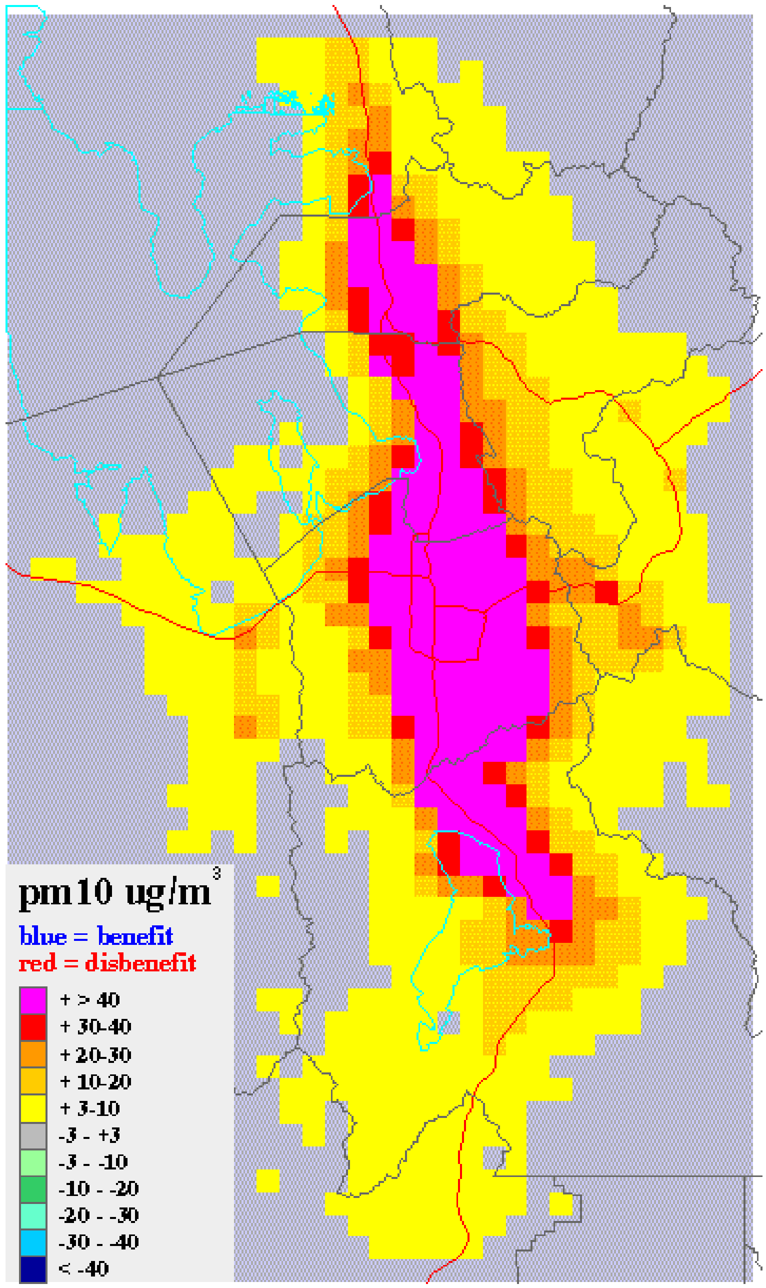


Figure 6-25. Sensitivity 12 (b34s12) – Change in daily average PM_{10} on February 13, 1996, due to double mobile source emissions

Elimination of surface deposition increases modeled PM_{10} throughout the domain as seen in **Figure 6-26** (b34s13). As expected, without deposition turned on, the model is no longer able to remove aerosols from the domain. The impact is greatest in the area with highest modeled concentrations, but the fractional reduction is likely similar throughout. This simulation shows the importance of properly treating removal processes in the model.

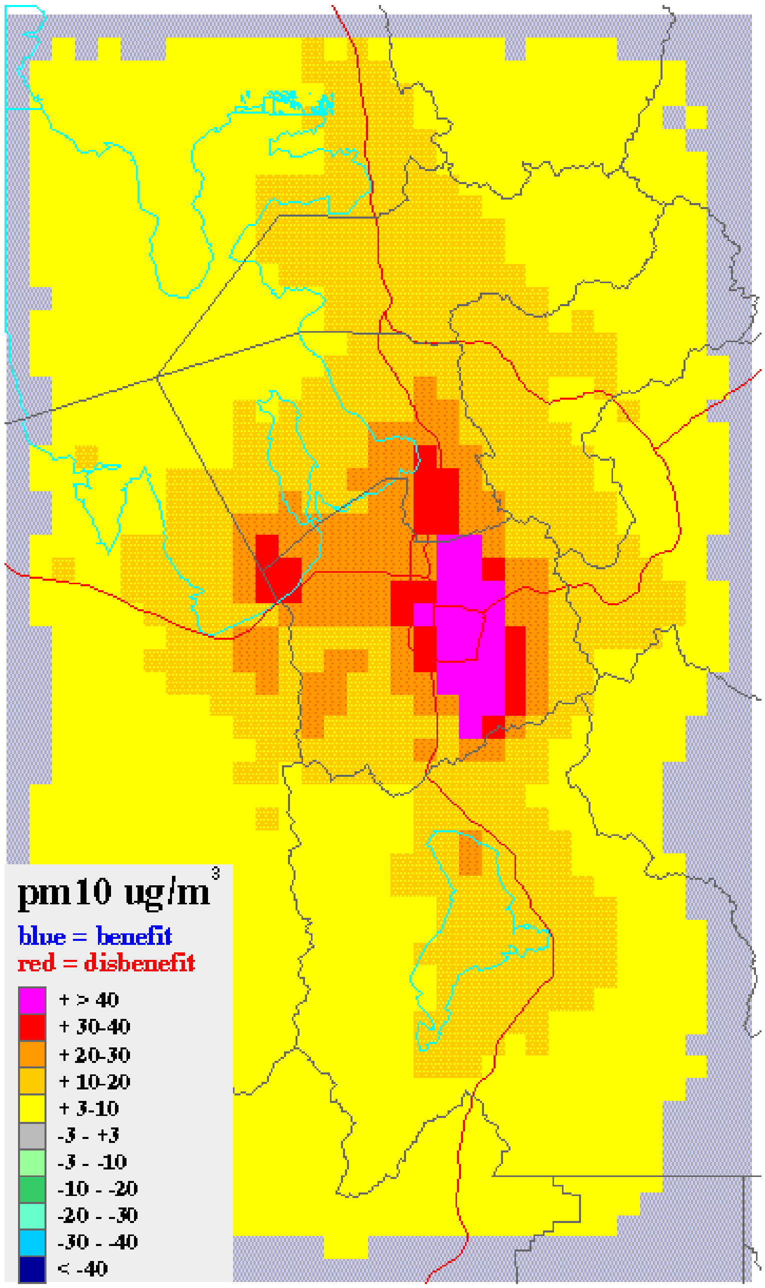


Figure 6-26. Sensitivity 13 (b34s13) – Change in daily average PM_{10} on February 13, 1996, due to elimination of surface deposition

Increasing wind speeds by 25% decreased modeled PM_{10} in the populated portion of the domain (b34s14, **Figure 6-27**). This result is consistent with the increased transport and diffusion by increased wind speeds. Slight increases in modeled PM_{10} are simulated in outlying areas where PM_{10} has been transported by higher wind speeds.

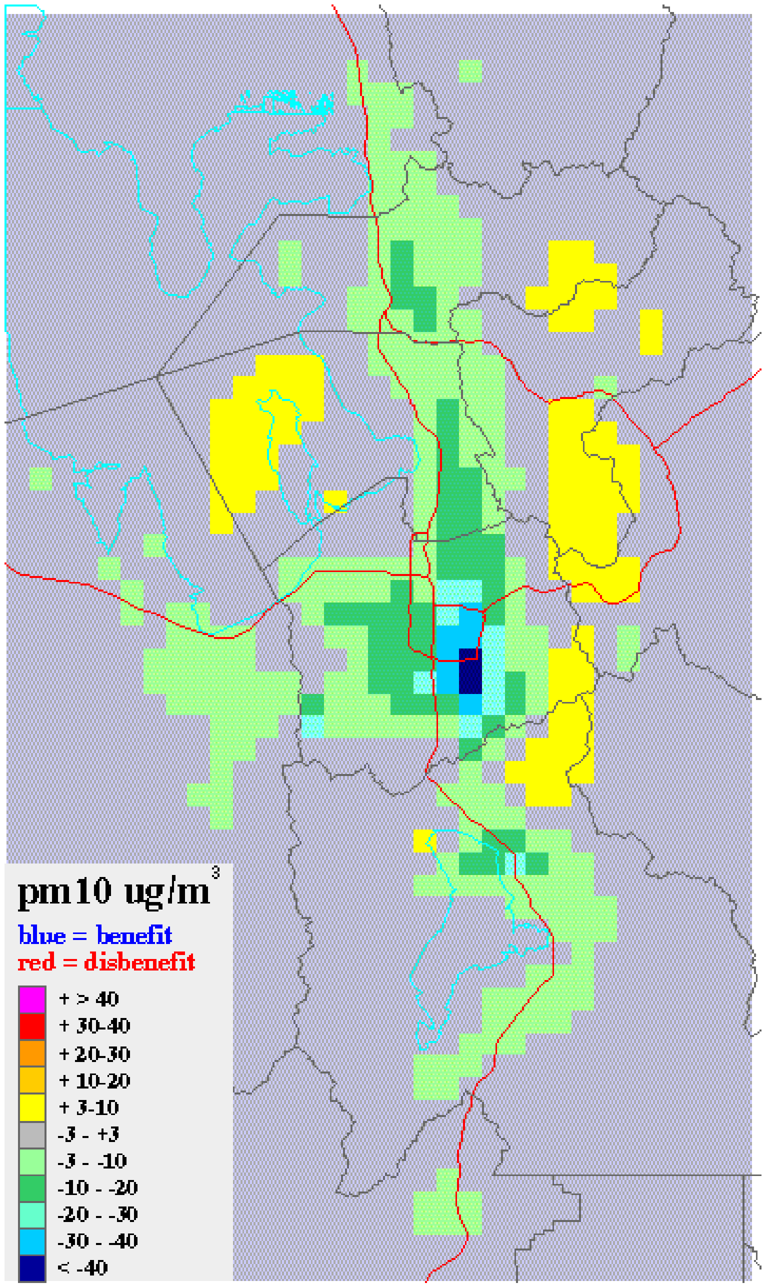


Figure 6-27. Sensitivity 14 (b34s14) – Change in daily average PM_{10} on February 13, 1996, due to increasing wind speeds by 25%

The effect of decreasing wind speeds by 25% (b34s15, **Figure 6-28**) is to increase modeled PM_{10} in all areas except those where the peak was displaced by transport. This result is consistent with reduced transport and diffusion when wind speeds are lower.

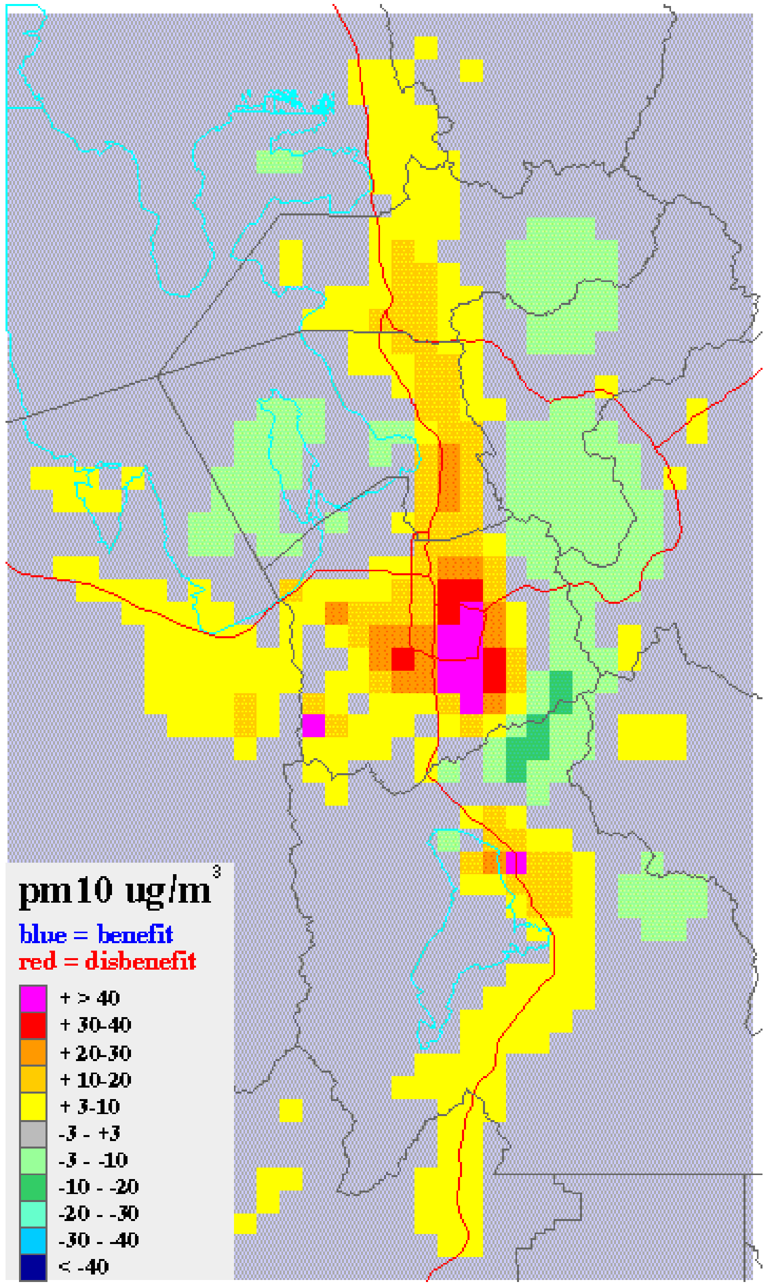


Figure 6-28. Sensitivity 15 (b34s15) – Change in daily average PM_{10} on February 13, 1996, due to decreasing wind speeds by 25%

As shown in **Figure 2-29** (b34s16), increases in the height of the diffusion break decrease modeled PM_{10} concentrations because the PM_{10} is diluted in a larger volume.

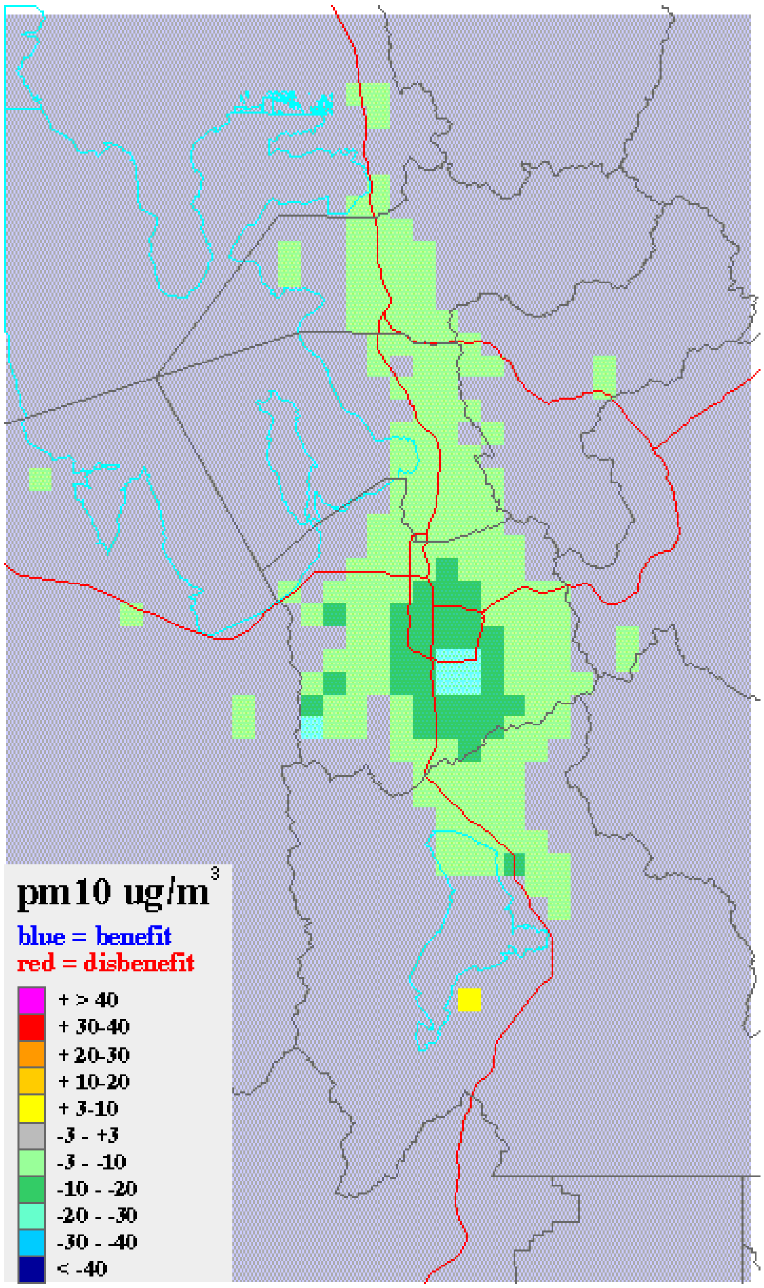


Figure 6-29. Sensitivity 16 (b34s16) – Change in daily average PM_{10} on February 13, 1996, due to increasing the diffusion break height by 25%

In Sensitivity 17, the diffusion break height was decreased by 25% resulting in higher PM_{10} concentrations (b34s17, **Figure 6-30**). This result was expected because both primary PM_{10} emissions and secondary PM_{10} precursor emissions are compressed into a smaller volume, leading to higher concentrations.

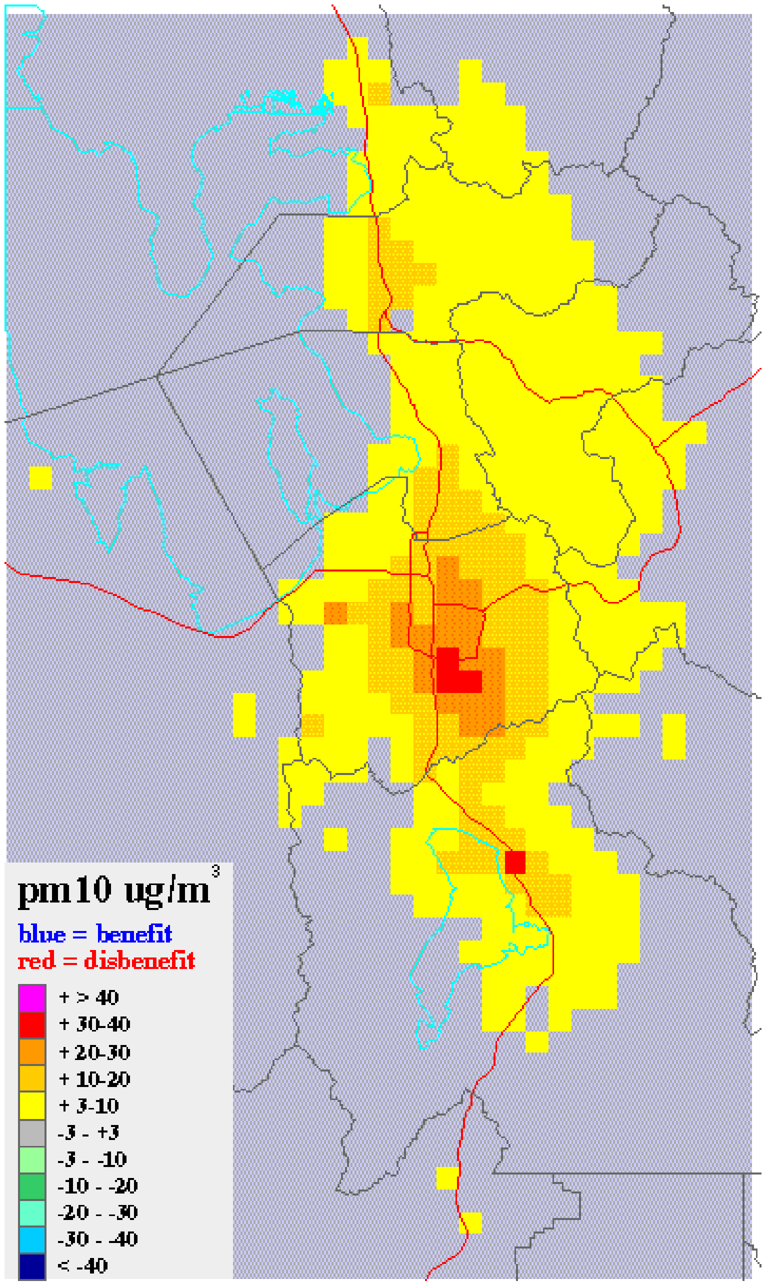


Figure 6-30. Sensitivity 17 (b34s17) – Change in daily average PM_{10} on February 13, 1996, due to decreasing the diffusion break height by 25%

Removing all fog from the simulation (Sensitivity 18, b34s18) resulted in increased PM_{10} in northern Salt Lake County as seen in **Figure 6-31**. This is due to decreased deposition and shows up in primary and nitrate PM_{10}. There are some decreases in outlying areas, which are primarily due to a decrease in sulfate in the North Salt Lake region where sulfur emissions are present.

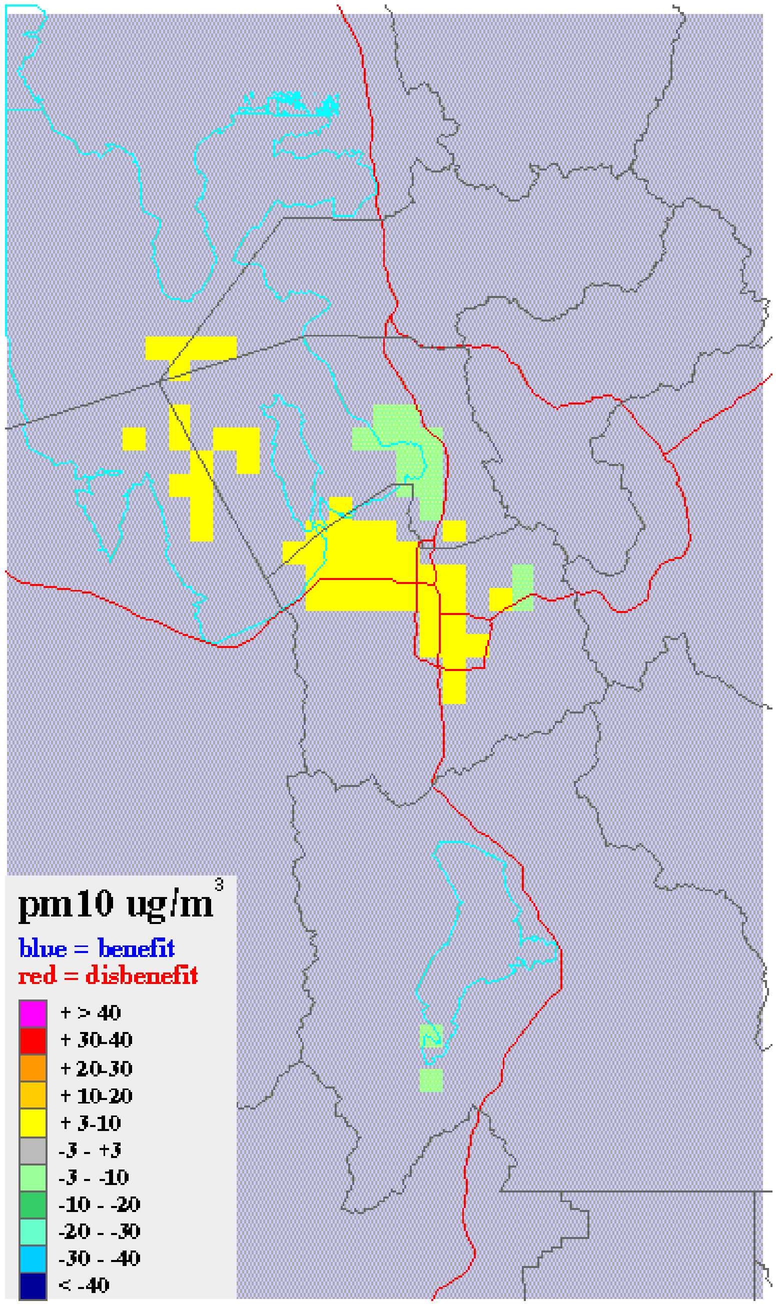


Figure 6-31. Sensitivity 18 (b34s18) – Change in daily average PM_{10} on February 13, 1996, due to removing fog in the simulation

In Sensitivity 19 (b34s19), adding fog across the entire domain results in a general decrease in modeled PM_{10} (**Figure 6-32**). The presence of fog in UAM-AERO increases nitrate and sulfate production but also increases deposition, which tends to decrease total PM_{10}. The increase in deposition tends to be more pronounced during the day when there is typically not much fog present. From this simulation, we see that nighttime-only fog allows enhanced secondary aerosol production without excessive deposition, which can lead to increased PM_{10} build up. However, the presence of fog during the daytime can result in decreased PM_{10} due to enhanced deposition.

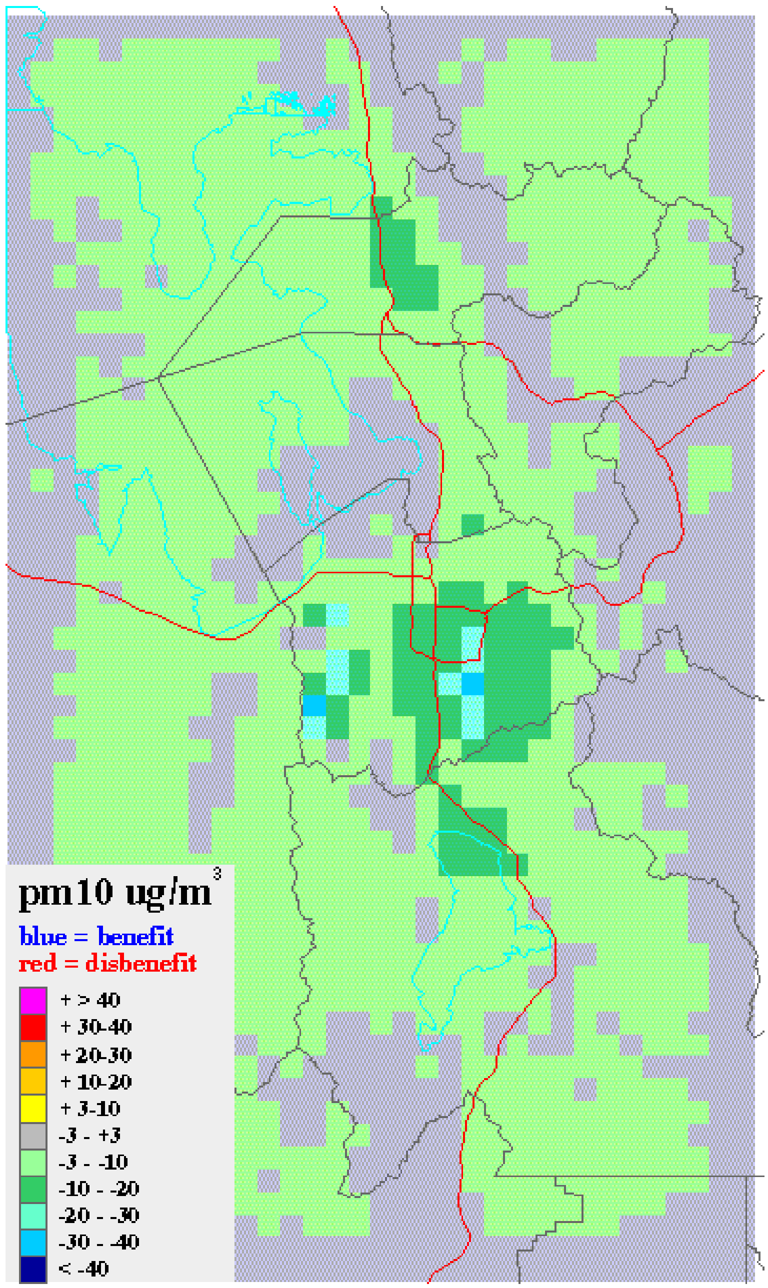


Figure 6-32. Sensitivity 19 (b34s19) – Change in daily average PM_{10} on February 13, 1996, due to including fog in all areas at all times

Sensitivity 20 demonstrates that even with a 50% reduction in ammonia emissions, modeled PM_{10} only decreases moderately (< 20 µg/m3) as seen in **Figure 6-33** (b34s20). This result suggests that there generally are sufficient ammonia emissions in the model simulation to maintain secondary aerosol formation. Here it is seen that even a significant decrease in ammonia only has a moderate influence.

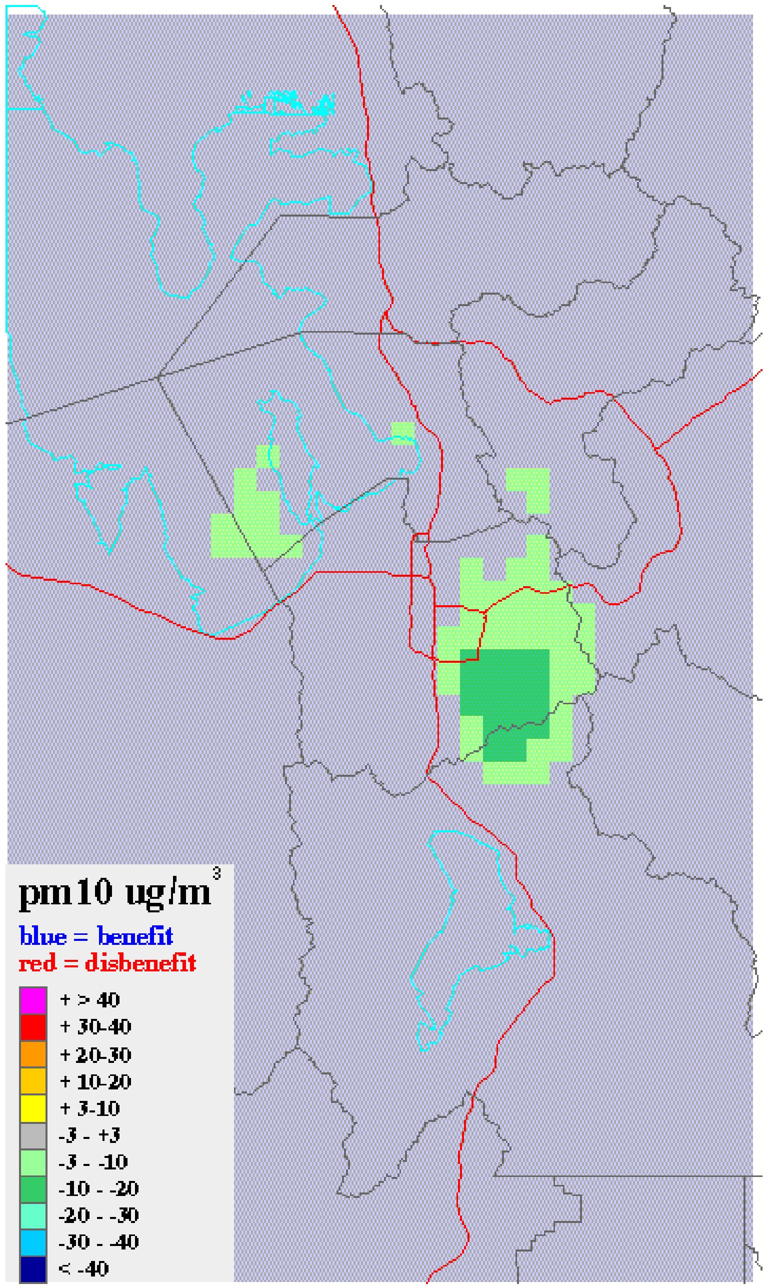


Figure 6-33. Sensitivity 20 (b34s20) – Change in daily average PM_{10} on February 13, 1996, due to a 50% reduction in ammonia emissions

6.7 Overall Assessment of Model Performance

Overall, the model simulates PM_{10} mass with a normalized error for all sites less than 40%. PM_{10} mass for sites in Salt Lake City tends to be underpredicted with biases ranging –10.1% on February 13 to –37.7% on February 15. PM_{10} mass concentrations for sites in Utah County are also underpredicted with biases ranging –19.2% on February 11 to –46.4% on February 13. Outside of Salt Lake and Utah counties, PM_{10} is generally overpredicted with biases ranging from –8.4% on February 15 (the only day with under prediction) to +50.3% on February 12.

The under predictions of PM_{10} mass in Salt Lake and Utah counties are due to under predictions in nitrate, sulfate, ammonium, and organic matter aerosol. The cause of the under predictions appears to be a spatial displacement of the predicted peaks from the observed locations. For example, the observed peak in Salt Lake County is at the North Salt Lake monitoring site while the predicted peak is displaced to the south and west. These displacements are due to uncertainties in the wind fields that were unable to be eliminated. However, when peak predicted concentrations are compared to observed concentrations without being paired in space, the biases are smaller.

While there is only limited speciated PM data outside Salt Lake and Utah counties, over predictions of PM_{10} mass appear to be a result of OTR.1 over predictions at the Magna monitoring station. This site is one of several locations where the model predicts high concentrations near large sources of OTR.1 emissions. Other areas include the area around the Geneva Steel plant in Utah County and the Kennecott copper mine.

Sensitivity and simulations show the model is most sensitive to emissions, wind speed, mixing height, deposition, and fog. Through a range of sensitivity simulations the model's sensitivity has been quantified allowing the estimation of the effects of uncertainty and model's response to emission controls.

When spatial displacement of peaks, hot spots, and emission inventory biases are considered, the model does a reasonable job of replicating the temporal and chemical evolution of PM_{10} in Salt Lake and Utah Counties. The model responds to emission changes in direction and magnitude in such a way that suggests it can be used confidently for policy development. While this simulation does not meet the performance criteria established for use in an absolute attainment demonstration, it can be used in a relative attainment demonstration if both site-specific and peak location Relative Reduction Factors (RRF) are used.

6.8 References

Tesche T.W., Georgopoulos P., Seinfeld J. H., Roth P. M., Lurmann F., and Cass G., (1990), *Improvement of Procedures for Evaluating Photochemical Models*, Final report to the California Air Resources Board, Contract No. A832-103.

U.S. EPA, (1991), *Guideline for Regulatory Application of the Urban Airshed Model*, EPA-450/4-91-013, U.S. Environmental Protection Agency, Research Triangle Park, NC.

U.S. EPA, (1999a), *Use of Models and Other Analyses in Attainment Demonstrations For The 8-Hour Ozone NAAQS*, EPA-454/R-99-004. U.S. Environmental Protection Agency, Research Triangle Park, NC.

U.S. EPA, (1999b), *Demonstrating Attainment of NAAQS for $PM_{2.5}$ and Reasonable Progress Reducing Regional Haze*, Concepts Paper Draft 4 (10/4/99), U.S. Environmental Protection Agency, Research Triangle Park, NC.

U.S. EPA, (2001), *Guidance for Demonstrating Air Quality Goals for $PM_{2.5}$ and Regional Haze*, Draft 2.1 (1/2/01), U.S. Environmental Protection Agency, Research Triangle Park, NC.

7.0 Relative Reduction Factor (RRF)

The basecase model results and the model performance evaluation indicate that the model performs adequately. Basecase sensitivity runs indicate that the model trends are robust. Therefore, rather than using absolute model results in an attainment demonstration, the future year model results are used in a relative sense. This approach is called the relative reduction factor (RRF) approach.

The relative reduction factor relies on a combination of observed design values and the trend in the model results at each monitor location. For each component species of PM_{10}, the future year results at a given monitor are divided by the basecase results at the same monitor and are then multiplied by the component-specific design value for that monitor. The component-specific design value is obtained by partitioning the PM_{10} design value for each monitor into the component species as obtained from observed speciated data at each monitor. These results are summed to produce the projected PM_{10} value at each monitor. This approach ties the model results to the design value. If the design value is above the PM_{10} NAAQS then the future year model results need to be reduced relative to the basecase results in order to demonstrate attainment. The RRF approach is outlined in EPA's draft modeling Guidance for PM2.5. The adaptation of EPA's guidance on the RRF approach is detailed in the PM10 SIP modeling protocol and summarized here.

7.1 RRF Procedure

- Determine the PM_{10} site-specific design value and the corresponding species-specific design value. The design values are based on the frequency of observations and are listed below:

Site	PM10	OTR	NO3	SO4	NH4	OM	EC	Cl	Na
AM	151	38.24	48.67	6.28	14.94	29.52	6.97	4.15	2.23
B4	93	12.55	45.99	5.57	13.93	10.13	2.34	2.23	0.27
BT	126	29.92	46.15	7.29	15.37	19.54	4.50	2.14	1.08
CW	130	30.95	48.70	5.68	15.37	22.88	3.07	2.16	1.19
LN	147	79.38	30.22	3.38	8.19	18.49	3.19	2.94	1.22
MG	110	22.00	50.25	6.33	15.58	9.41	5.49	0.27	0.66
NP	120	51.72	28.44	2.96	7.60	22.14	4.05	1.92	1.16
N2	157	33.88	54.52	9.50	17.49	32.83	4.14	2.99	1.65
OG	98	33.49	28.05	3.63	8.35	16.49	5.26	1.62	1.12
WO	135	63.00	30.66	3.73	7.54	20.12	5.91	3.06	0.98
WT	80	26.16	26.88	3.34	7.83	9.73	5.00	0.50	0.56

  The total mass of measured PM_{10} is divided into mulitple components. Because there are few sites which have speciated data during the February 1996 episode, the speciated observations are used to partition the PM_{10} design value into component species. If there is more than one speciated sample available at a given site, then the fraction of each species is calculated from the average of the observations.

- For each site, develop component-specific relative reduction factors to be applied to the current site-specific observed design values derived for each component.

The relative reduction factor is computed by taking a weighted bilinear interpolation of the modeled results for a given species in the four grid cells nearest each monitor (the grid cell containing the monitor and the three others which are nearest). This value is computed for the basecase results and for the future year or control strategy results in question. The RRF is the ratio between the future year result and the basecase result.

- At each monitoring site, project future PM_{10} design values by multiplying each component-specific relative reduction factor times the corresponding component-specific observed design value. Add the results to obtain the estimated future site-specific design value for PM_{10}.
- Compare each projected PM_{10} value with the PM_{10} NAAQS of 150 $\mu g/m^3$.

If all of the projected PM_{10} design values are = 150 $\mu g/m^3$, the attainment test is passed.

Furthermore, in the event that there are modeled high values which are not “near” a monitoring location and therefore are not subject to the above analysis, then DAQ conducted the following screening procedure.

- In each nonattainment County select any grid cell with a current (1996) modeled concentration 20% greater than the highest modeled concentration in any of the cells "near" a monitor.
- If no cells are found, the screening test is passed.
- If a cell, or cells, are found in either County create a 4 x 4 cell window around that cell to calculate a spatially averaged RRF.
- In Salt Lake County use the North Salt Lake monitor for the design value.
- In Utah County use the Lindon monitor for the design value.
- Multiply the RRF times the design value for the modeled attainment test for any selected areas away from the monitor locations.
- If the result is below the PM_{10} NAAQS, then the area in question attains the standard.

8.0 Hotspot Analysis

The modeled attainment test for PM_{10}, whether using a relative or absolute approach, has no ability to evaluate attainment at locations where there is no nearby monitor. Consequently, DAQ proposes to use a Hot Spot Analysis, similar to that discussed in EPA's "Guidance for Demonstrating Attainment of Air Quality Goals for $PM_{2.5}$ and Regional Haze" (Draft, March 27, 2000). DAQ recognizes that EPA's guidance document is specific to $PM_{2.5}$ but DAQ believes that this analysis will be robust for PM_{10} because the hot spot analysis relies on emissions of primary particulates that are often larger than 2.5 microns.

The hot spot analysis will focus on large sources of primary PM_{10}. Whereas secondary PM_{10} is often spatially uniform, primary PM_{10} is often linked to particular sources of primary particulates. Consequently, we believe that the monitoring network can accurately represent secondary particulate concentrations but that there may be areas within the nonattainment areas that do not have nearby monitors that might have higher primary PM_{10} concentrations than the distant monitors represent.

A hotspot is a major source of PM_{10} that meets the following criteria:

- The source is within the non-attainment area but not "near" a PM_{10} monitoring location;
- The source has PM_{10} emissions that are significantly (i.e., 20%) above PM_{10} emissions near a monitoring location;
- The source is a major source for PM_{10}.

For this project, "near" is defined as a 3 x 3 grid cell region centered on the grid cell containing a monitor. The maximum PM_{10} emissions in a region "near" a monitor is identified and compared to PM_{10} emissions in areas that are not near a monitor.

For Utah County, the maximum PM_{10} emissions near a monitor is 1151 tons/year in 2003 with banked emissions and allowable emissions included. There are no individual sources nor group of sources within a single grid cell whose emissions are greater than 1151 tons/year in Utah County. Therefore, no hotspot analysis is required for Utah County.

For Salt Lake County, the maximum PM_{10} emissions near a monitor is 366 tons/year in 2003 with banked emissions included. The only source or group of sources within a single grid cell in Salt Lake County with higher emissions than this is the Kennecott Mine and Copperton Concentrator whose PM_{10} emissions are 832 tons/year. The location of the grid cell boundaries and the physical boundaries of the Kennecott pit indicate that the grid cell from which 832 tons/year are emitted in the UAM-AERO model is fully contained within Kennecott's property boundary (Figure 8-1). Therefore this hotspot is not ambient air and therefore is not governed under the National Ambient Air Quality Standards (NAAQS).

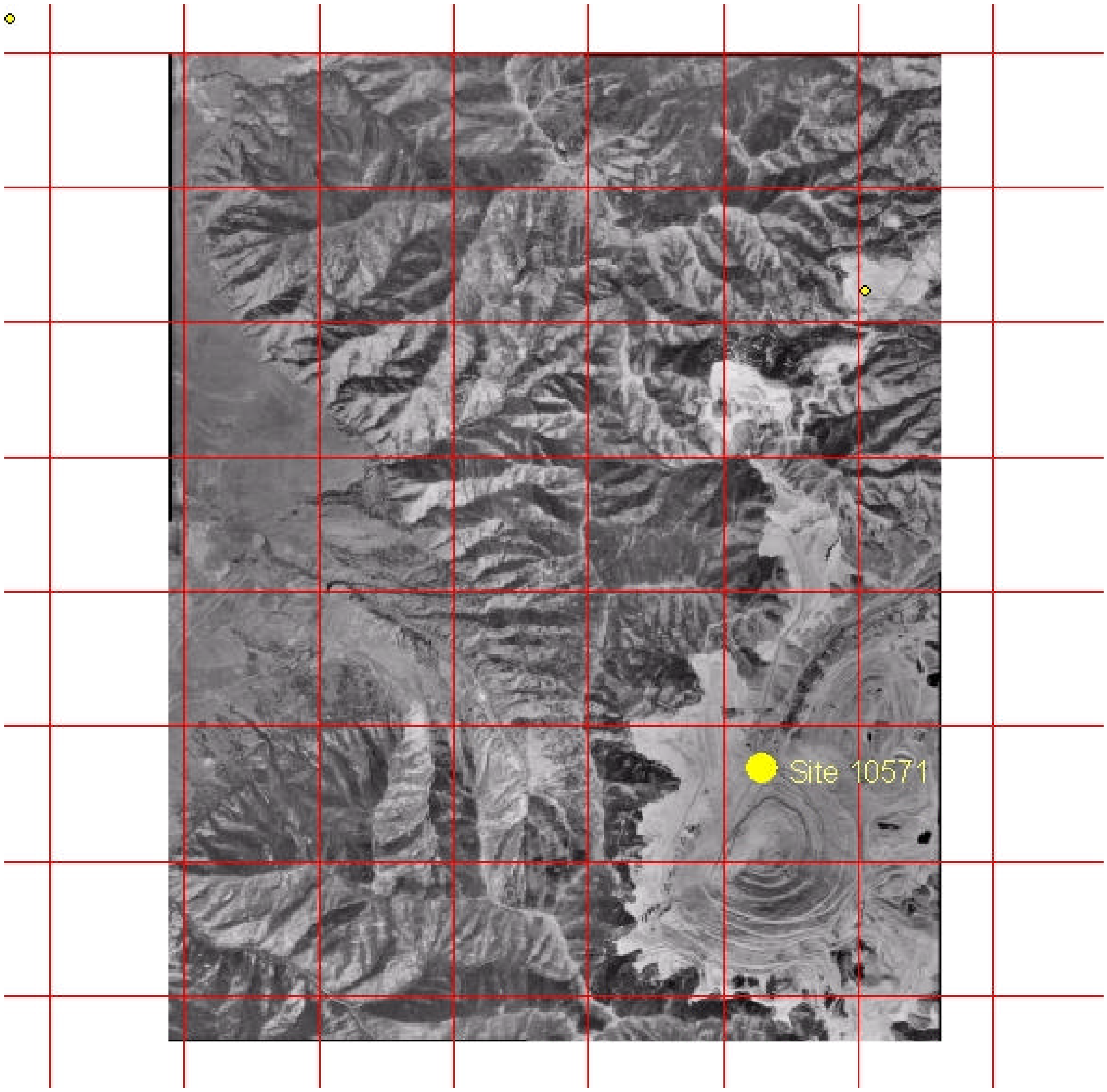


Figure 8-1. Kennecott Mine and Copperton Concentrator (Site 10571) with 4-km grid cell boundaries overlaid.
This image illustrates that the pit extends beyond the boundaries of the grid cell and therefore the grid cell containing Site 10571 cannot be considered to be ambient air.

9.0 Summary/Conclusions

Although the UAM-AERO modeling results were not used in the PM_{10} SIP revisions submitted to EPA in 2002, the results of the base case model performance evaluation and sensitivity runs indicate that UAM-AERO behaves appropriately for the Wasatch Front Region. Major uncertainties in the model are due to a lack of meteorological and pollutant observations. Improved data sets, which are available during recent years, encourage DAQ about the usefulness of these models and modeling techniques for future projects. Even without a lot of meteorological and pollutant observations during 1996, the model responds to emission changes in direction and magnitude in such a way that suggests it can be used confidently for policy development. The UAM-AERO/SMOKE modeling system will be used by DAQ for future analyses of pollution issues in this region during time periods for which more data are available to validate the model.

10.0 Appendices

10.1 Chapter 3 Appendix A

10.1.1 Technical Notes For Developing Gridded Land Use at 2 and 4 Kilometer Resolution

12/20/99

My method for getting the landuse file ready for uam-aero

The grid, gwalu_grd is a 30m grid from agrc of 1997 parcel based landuse done for qget. A lot of it does not function perfectly for uam needs so I am going to combine it with GIRAS data to get the lu categories I need. The main thing I will get out of this grid will be the urban residential and commercial, and the agricultural areas.

The eleven lu categories used in uam for the creation of the terrain file via CRETER are the same categories used in uam-aero for their land use file. One also uses CRETER to create a terrain file for aero, but unlike uam, aero also uses an explicit land use file. So that is what I am setting about to create.

Current location: /trinidad/uam_aero/ws.uamaero/ws.lu
Arc: additem GWALU_GRD.vat GWALU_GRD.vat lucode 2 3 i

Arc: tables
Enter Command: sel GWALU_GRD.vat
28 Records Selected.

Enter Command: list

Record	VALUE	COUNT	DESCRIPTION	LUCODE
1	0	10565809	No Data	0
2	1	3823306	USFS	0
3	2	2531663	BLM	0
4	3	622098	State of Utah	0
5	6	356990	Military	0
6	7	1058	National Park/Monument	0
7	8	237209	Utah State Parks and Rec.	0
8	9	487359	State Wildlife Management	0
9	11	115272	National Wildlife refuge	0
10	12	429719	Wilderness	0
11	13	97515	Federal Grasslands	0
12	39	3493571	Water Bodies	0
13	40	1644	Intermittent Water Bodies	0
14	101	929568	R1 - Single Family	0
15	102	12522	R2 - 2-4 Units	0
16	103	17232	R3 - Multi-family	0
17	104	10544	R4 - Mobile Homes	0
18	105	555	R5 - Group Quarters	0
19	106	99908	C1 - Retail	0
20	107	110566	C2 - Industrial	0
21	108	8224	C3 - Warehouse	0

22	109	2720	C4 - Office	0

Continue?

23	110	207189	C5 - Special Purpose	0
24	111	474138	Exempt	0
25	112	939118	Agriculture	0
26	113	1281149	Vacant	0
27	119	28969	Parks / Open Space	0
28	212	865951	Irrigated Cropland	0

Enter Command: resel value > 100 and value < 111
10 Records Selected.
Enter Command: calc lucode = 1

Enter Command: asel
Enter Command: resel value = 212 or value = 112
Enter Command: calc lucode = 2

Enter Command: asel
Enter Command: resel value = 13
Enter Command: calc lucode = 3

Enter Command: asel
Enter Command: resel value = 119
Enter Command: calc lucode = 3

12/21/99

I now have urban, ag, and range defined. Next step is to break them out as separate grids.

Grid: ag30_grd = test(GWALU_GRD, 'lucode = 2')
Grid: urb30_grd = test(GWALU_GRD, 'lucode = 1')
Grid: rng30_grd = test(GWALU_GRD, 'lucode = 3')

The test function puts a 1 in the cell that has the preferred land use and a 0 in all others.

Now I want to get VALUE to represent the number of sq. meters
Grid: urb_sqm_grd = (URB30_GRD * 900)
Grid: ag_sqm_grd = (AG30_GRD * 900)
Grid: rng_sqm_grd = (RNG30_GRD * 900)
Do a QA to see if things are as they should be
Grid: list AG30_GRD.vat

Record	VALUE	COUNT
1	0	25946497
2	1	1805069

Grid: list AG_SQM_GRD.vat

Record	VALUE	COUNT
1	0	25946497
2	900	1805069

Looks good!
Now create a value grid
Grid: dom2k_grd = polygrid(../aero_2km,#,#,#,2000)

Now see if I can get the values into a 2km resolution.

Grid: setcell minof
Grid: ag2km_grd = zonalsum(DOM2K_GRD,AG_SQM_GRD)
Grid: ag2km_rsmp = resample(ag2km_grd,2000)
        Do some QA

12/23/99

Can't seem to get the QA to do what I want in terms of comparing my resampled grid to the original 30 meter grid. At this point I think that is ok. I am going to go on with it and see if I can do some comparisons when I get my final coverage.

Repeat the process above to get 2km grids for urban and range.
Grid: setcell minof
Grid: urb2km_grd = zonalsum(DOM2K_GRD,URB_SQM_GRD)
Grid: urb2km_rsmp = resample(urb2km_grd,2000)
Grid: rng2km_grd = zonalsum(DOM2K_GRD,RNG_SQM_GRD)
Grid: rng2km_rsmp = resample(rng2km_grd,2000)

Grid: RNG2KM_int = int(RNG2KM_RSMP)
Grid: URB2KM_int = int(URB2KM_RSMP)
Value range for /trinidad/uam_aero/ws.uamaero/ws.lu/urb2km_int exceeds 100000
and number of unique values exceeds 500.
Please use BUILDVAT if a VAT is required.
Grid: buildvat URB2KM_int
Grid: kill AG2KM_INT all
Killed AG2KM_INT with the ALL option
Grid: AG2KM_INT = int(AG2KM_RSMP)
Value range for /trinidad/uam_aero/ws.uamaero/ws.lu/ag2km_int exceeds 100000
and number of unique values exceeds 500.
Please use BUILDVAT if a VAT is required.
Grid: buildvat AG2KM_int

Turn these into coverages
Grid: AG2KM_cov = gridpoly(AG2KM_INT)
Grid: RNG2KM_cov = gridpoly(RNG2KM_INT)
Grid: URB2KM_cov = gridpoly(URB2KM_INT)

        Now do some QA in ap and see if things look right
QA looks good on these grids. I compared the final covs with the urb2km_grd series of 30 meter grids and they match well.

Step 2 in creating the uam-aero landuse file

Get rid of the intemeadiate grids created above. Can always recreate them if needed.

Prepare the 3 lu covs to integrate lu items into 1 coverage.

Arc: tables

Enter Command: sel AG2KM_COV.pat
Enter Command: alter grid-code
Item Name: ag

Do the same for urban and range
Create the initial lu coverage
Arc: copy ../aero_2km ./aero_2km
Arc: identity AERO_2KM AG2KM_COV lu1_cov
Arc: identity lu1_cov RNG2KM_COV lu2_cov
Arc: identity lu2_cov URB2KM_COV lu3_cov
Drop a few items
Now deal with the giras landuse and get it identitied into the final landuse covs.
Arc: additem GIRAS_COV.pat GIRAS_COV.pat gc 2 2 i
Arc: clip GIRAS_COV AERO_2KM giras_clp
Enter Command: sel giras_clp.pat
Enter Command: resel lucode > 10 and lucode < 20
Enter Command: calc gc = 1
Enter Command: sel
Arc: polygrid giras_clp URBG_GRD gc
Converting polygons from giras_clp to grid URBG_GRD
Cell Size (square cell): 100
Convert the Entire Coverage? (Y/N): y
Number of Rows = 2641
Number of Columns = 1940

Enter Command: sel giras_clp.pat
Enter Command: calc gc = 0
Enter Command: resel lucode > 20 and lucode < 30
657 Records Selected.
Enter Command: calc gc = 1
Enter Command: sel
Arc: polygrid giras_clp agg_grd gc
Converting polygons from giras_clp to grid agg_grd
Cell Size (square cell): 100

Grid: asel ws.work_covs/giras_clp poly
Grid: calc ws.work_covs/giras_clp poly gc = 0
Grid: resel ws.work_covs/giras_clp poly lucode > 30 and lucode < 40
WS.WORK_COVS/GIRAS_CLP polys : 2245 of 8163 selected.
Grid: calc ws.work_covs/giras_clp poly gc = 1
Grid: rngg_grd = polygrid(ws.work_covs/giras_clp,gc,#,#,100)

Grid: asel giras_clp poly
GIRAS_CLP polys : 8163 of 8163 selected.
Grid: calc giras_clp poly gc = 0
Grid: resel giras_clp poly lucode = 41
GIRAS_CLP polys : 579 of 8163 selected.
Grid: calc giras_clp poly gc = 1
Grid: decidg_grd = polygrid(giras_clp,gc,#,#,100)

Grid: asel giras_clp poly

GIRAS_CLP polys : 8163 of 8163 selected.
Grid: calc giras_clp poly gc = 0
Grid: resel giras_clp poly lucode = 42
GIRAS_CLP polys : 883 of 8163 selected.
Grid: calc giras_clp poly gc = 1
Grid: evgrg_grd = polygrid(giras_clp,gc,#,#,100)

Grid: asel giras_clp poly
GIRAS_CLP polys : 8163 of 8163 selected.
Grid: calc giras_clp poly gc = 0
Grid: resel giras_clp poly lucode = 43
GIRAS_CLP polys : 463 of 8163 selected.
Grid: calc giras_clp poly gc = 1
Grid: mixg_grd = polygrid(giras_clp,gc,#,#,100)

Grid: asel giras_clp poly
GIRAS_CLP polys : 8163 of 8163 selected.
Grid: calc giras_clp poly gc = 0
Grid: resel giras_clp poly lucode > 50 and lucode < 60
GIRAS_CLP polys : 198 of 8163 selected.
Grid: calc giras_clp poly gc = 1
Grid: watg_grd = polygrid(giras_clp,gc,#,#,100)

Grid: asel giras_clp poly
GIRAS_CLP polys : 8163 of 8163 selected.
Grid: calc giras_clp poly gc = 0
Grid: resel giras_clp poly lucode = 62
GIRAS_CLP polys : 114 of 8163 selected.
Grid: calc giras_clp poly gc = 1
Grid: wetg_grd = polygrid(giras_clp,gc,#,#,100)

Grid: asel giras_clp poly
GIRAS_CLP polys : 8163 of 8163 selected.
Grid: calc giras_clp poly gc = 0
Grid: resel giras_clp poly lucode > 70 and lucode < 80
GIRAS_CLP polys : 402 of 8163 selected.
Grid: calc giras_clp poly gc = 1
Grid: barg_grd = polygrid(giras_clp,gc,#,#,100)

Grid: asel giras_clp poly
GIRAS_CLP polys : 8163 of 8163 selected.
Grid: calc giras_clp poly gc = 0
Grid: resel giras_clp poly lucode > 70 and lucode < 80
GIRAS_CLP polys : 402 of 8163 selected.
Grid: calc giras_clp poly gc = 1
Grid: barg_grd = polygrid(giras_clp,gc,#,#,100)

Now go through the process I went through with the agrc grid.

First get the values in sq meters
Grid: AGG_GRD2 = (AGG_GRD * 10000)

Grid: BARG_GRD2 = (BARG_GRD * 10000)
Grid: DECIDG_GRD2 = (DECIDG_GRD * 10000)
Grid: EVGRG_GRD2 = (EVGRG_GRD * 10000)
Grid: MIXG_GRD2 = (MIXG_GRD * 10000)
Grid: RKYG_GRD2 = (RKYG_GRD * 10000)
Grid: URBG_GRD2 = (URBG_GRD * 10000)
Grid: WATG_GRD2 = (WATG_GRD * 10000)
Grid: WETG_GRD2 = (WETG_GRD * 10000)
Grid: rngg_grd2 = (rngg_grd * 10000)

Now sum up the values

Grid: AGG_GRD3 = zonalsum(DOM2K_GRD,AGG_GRD2)
Grid: BARG_GRD3 = zonalsum(DOM2K_GRD,BARG_GRD2)
Grid: DECIDG_GRD3 = zonalsum(DOM2K_GRD,DECIDG_GRD2)
Grid: EVGRG_GRD3 = zonalsum(DOM2K_GRD,EVGRG_GRD2)
Grid: MIXG_GRD3 = zonalsum(DOM2K_GRD,MIXG_GRD2)
Grid: RKYG_GRD3 = zonalsum(DOM2K_GRD,RKYG_GRD2)
Grid: URBG_GRD3 = zonalsum(DOM2K_GRD,URBG_GRD2)
Grid: WATG_GRD3 = zonalsum(DOM2K_GRD,WATG_GRD2)
Grid: WETG_GRD3 = zonalsum(DOM2K_GRD,WETG_GRD2)
Grid: rngg_grd3 = zonalsum(DOM2K_GRD,rngg_grd2)

Now resample to a 2km grid cell

Grid: AGG_GRD4 = resample(AGG_GRD3,2000)
Grid: BARG_GRD4 = resample(BARG_GRD3,2000)
Grid: DECIDG_GRD4 = resample(DECIDG_GRD3,2000)
Grid: EVGRG_GRD4 = resample(EVGRG_GRD3,2000)
Grid: MIXG_GRD4 = resample(MIXG_GRD3,2000)
Grid: RKYG_GRD4 = resample(RKYG_GRD3,2000)
Grid: URBG_GRD4 = resample(URBG_GRD3,2000)
Grid: WATG_GRD4 = resample(WATG_GRD3,2000)
Grid: WETG_GRD4 = resample(WETG_GRD3,2000)
Grid: rngg_grd4 = resample(rngg_grd3,2000)

Create integer grids

Grid: AGG_GRD5 = int(AGG_GRD4)
Grid: BARG_GRD5 = int(BARG_GRD4)
Grid: DECIDG_GRD5 = int(DECIDG_GRD4)
Grid: EVGRG_GRD5 = int(EVGRG_GRD4)
Grid: MIXG_GRD5 = int(MIXG_GRD4)
Grid: RKYG_GRD5 = int(RKYG_GRD4)
Grid: URBG_GRD5 = int(URBG_GRD4)
Grid: WATG_GRD5 = int(WATG_GRD4)
Grid: WETG_GRD5 = int(WETG_GRD4)
Grid: rngg_grd5 = int(rngg_grd4)

Now turn these into coverages

Grid: AGG_cov = gridpoly(AGG_GRD5)
Grid: BARG_cov = gridpoly(BARG_GRD5)
Grid: DECIDG_cov = gridpoly(DECIDG_GRD5)
Grid: EVGRG_cov = gridpoly(EVGRG_GRD5)
Grid: MIXG_cov = gridpoly(MIXG_GRD5)
Grid: RKYG_cov = gridpoly(RKYG_GRD5)
Grid: URBG_cov = gridpoly(URBG_GRD5)
Grid: WATG_cov = gridpoly(WATG_GRD5)
Grid: WETG_cov = gridpoly(WETG_GRD5)
Grid: rngg_cov = gridpoly(rngg_grd5)

Get rid of all these grids

Alter the item names on all thes new coverages so that they can be identitied with lu3_cov

Enter Command: sel AGG_COV.PAT
Enter Command: alter GRID-CODE
Item Name: agg

Enter Command: sel RNGG_COV.PAT
Enter Command: alter grid-code
Item Name: rngg

Enter Command: sel BARG_COV.PAT
Enter Command: alter grid-code
Item Name: barg

Enter Command: sel DECIDG_COV.PAT
Enter Command: alter grid-code
Item Name: decidg

Enter Command: sel EVGRG_COV.PAT
Enter Command: alter grid-code
Item Name: EVGRG

Enter Command: sel MIXG_COV.PAT
Enter Command: alter grid-code
Item Name: MIXG

Enter Command: sel RKYG_COV.PAT
Enter Command: alter grid-code
Item Name: RKYG

Enter Command: sel URBG_COV.PAT
Enter Command: alter grid-code
Item Name: URBG

Enter Command: sel WATG_COV.PAT
Enter Command: alter grid-code
Item Name: WATG

Enter Command: sel WETG_COV.PAT
Enter Command: alter grid-code
Item Name: WETG

Now Identity up to get a semi-final landuse coverage.

Arc: identity LU3_COV AGG_COV lu4_cov
Arc: identity lu4_cov BARG_COV lu5_cov
Arc: identity lu5_cov DECIDG_COV lu6_cov
Arc: identity lu6_cov EVGRG_COV lu7_cov
Arc: identity lu7_cov MIXG_COV lu8_cov
Arc: identity lu8_cov RKYG_COV lu9_co
Arc: identity lu9_co RNGG_COV lu10_cov
Arc: identity lu10_cov URBG_COV lu11_cov
Arc: identity lu11_cov WATG_COV lu12_cov
Arc: identity lu12_cov WETG_COV lu13_cov

Now, drop the unneeded items and kill all of the intermediate lu covs.

&&&&***&&&&**

Add the final land use items to lu13_cov and then create an aml to give a final land use code to each cell.

Arc: copy LU13_COV aero_lu_cov

As I look at this land use coverage the numbers are not terribly clean but that is because I am working with different data sets. I should be able to recalculate things and then compare the final lu cov with the original giras coverage and agr grid to see how they match up.

The plan for the aml is to process it one cell at a time . Call the aml "calclu.aml".
1st create final lu items
2nd calc -9999 = 0
check if every lu items is 0
    if so go to next cell
if not do max stats on each item

1/3/00

Have an aml created, calclu2.aml, with the help of ESRI, to process the land use coverage. The basic documentation of how the final aero land use for each grid cell gets calculated is contained within the aml. However, here are are a few added comments.

As mentioned above, lu13_cov is the final concoction of qget and usgs land use. Any modifications to that data set will always be done by copying that coverage and then working on the derived coverage. EXCEPT that I am going to change the -9999 values in lu13_cov to 0.

In order to get the best use out of the agr/qget data I am going to recalculate any of the ag and urb items so that if the usgs agricultural is larger than the agr urban or the usgs urban is larger than the agr agricultural then the agr items will be recalculated to be 10 higher than the usgs so that the grid will be properly classed based on the latest, highest resolution data. This will be commented in the aml.

AERO_LU_COV IS NOW DONE, LAND USE FOR AERO NOW EXISTS.

2/4/00

Things have changed in the last month in terms of the domain size. It is much smaller. So, now I need to clip this coverage and then redo the cell-id.

Arc: clip AERO_LU_COV ../AERO3_2KM AERO_3_lu
Bring over a coverage to get the proper cell-id into the clipped cov.
Arc: copy ../aero3_2km ./aero3_2km

Put the old coverages of the larger domain into the archive workspace, ws.work_covs.
Did the copying now kill the covs from this ws.
Arc: killem AERO_2KM AERO_LU_COV LU13_COV
Then tar up the archive workspace.

Arc: dropitem AERO_3_LU.pat AERO_3_LU.pat CELL-ID

Arc: identity AERO_3_LU AERO3_2KM AERO_3_LU2
Now I have the correct cell-id in the coverage. Just drop the unecessary items and rename the coverage back to aero_3_lu.

Arc: tables
Enter Command: sel AERO_3_LU.pat
Enter Command: unload aero.lu cell-id x-coord y-coord aero-lu

Now create a map comp and a gif of the land use.
Add an item for the color coding, calc the item, then create the aml to create the map.

2/7/00 Note to myself

I see when I create the map that for some reason in the wetlands and on the tip of Promontory Pt. There is urban land I am going to go into AERO_3_LU and change these to wetlands and range respectively.

Found some more land use categories that need to be changed, mainly in the GSL. Will change those and then visually check each of the other categories to see if I can spot any other problems.

11/21/00

Redoing the uam-aero domain to a 4 km resolution rather than 2 km. Will now use the documentation in notes.sdw to create a set of procedures and possibly amls to create a 4 km land use data set.

Actually, have another idea: disaggregate this data in way that is defensibly logical. What I will do is:

1. polygrid a bunch of times, 1 for each lu item

2. blocksum each lu at 4 km
3. resample to 4km
4. convert back to polys
5. identity all of these back up into 1 4km coverage
6. run that cursor aml on the coverage to get the final lu

Current location
Workspace: /TRINIDAD/UAM_AERO/WS.UAMAERO/WS.LU

Arc: copy AERO_3_LU AERO_3_LU2

Arc: polygrid AERO_3_LU2 ag_grd ag
Converting polygons from AERO_3_LU2 to grid ag_grd
Cell Size (square cell): 2000
Convert the Entire Coverage? (Y/N): y
Number of Rows = 113
Number of Columns = 67

Arc: polygrid AERO_3_LU2 RNG_grd RNG
Arc: polygrid AERO_3_LU2 URB_grd urb
Arc: polygrid AERO_3_LU2 AGG_grd agg
Arc: polygrid AERO_3_LU2 DECIDG_grd DECIDG
Arc: polygrid AERO_3_LU2 EVGRG_grd EVGRG
Arc: polygrid AERO_3_LU2 MIXG_grd MIXG
Arc: polygrid AERO_3_LU2 RKYG_grd RKYG
Arc: polygrid AERO_3_LU2 RNGG_grd RNGG
Arc: polygrid AERO_3_LU2 URBG_grd URBG
Arc: polygrid AERO_3_LU2 WATG_grd WATg
Arc: polygrid AERO_3_LU2 WETG_grd WETG
Arc: polygrid AERO_3_LU2 BARG_grd BARG

Grid: buildvat AGG_GRD
Grid: buildvat URB_GRD

Grid: AGG_GRD4 = blocksum(AGG_GRD,rectangle,2,2)
Grid: AG_GRD4 = blocksum(AG_GRD,rectangle,2,2)

Grid: BARG_GRD4 = blocksum(BARG_GRD,rectangle,2,2)
Grid: DECIDG_GRD4 = blocksum(DECIDG_GRD,rectangle,2,2)
Grid: EVGRG_GRD4 = blocksum(EVGRG_GRD,rectangle,2,2)
Grid: MIXG_GRD4 = blocksum(MIXG_GRD,rectangle,2,2)
Grid: RKYG_GRD4 = blocksum(RKYG_GRD,rectangle,2,2)
Grid: RNGG_GRD4 = blocksum(RNGG_GRD,rectangle,2,2)
Grid: RNG_GRD4 = blocksum(RNG_GRD,rectangle,2,2)
Grid: URBG_GRD4 = blocksum(URBG_GRD,rectangle,2,2)
Grid: URB_GRD4 = blocksum(URB_GRD,rectangle,2,2)
Grid: WATG_GRD4 = blocksum(WATG_GRD,rectangle,2,2)
Grid: WETG_GRD4 = blocksum(WETG_GRD,rectangle,2,2)

Grid: setwindow minof

Grid: AGG_GRD4a = resample(AGG_GRD4,4000)
Grid: AG_GRD4a = resample(AG_GRD4,4000)
Grid: BARG_GRD4a = resample(BARG_GRD4,4000)
Grid: DECIDG_GRD4a = resample(DECIDG_GRD4,4000)
Grid: EVGRG_GRD4a = resample(EVGRG_GRD4,4000)
Grid: MIXG_GRD4a = resample(MIXG_GRD4,4000)
Grid: RKYG_GRD4a = resample(RKYG_GRD4,4000)
Grid: RNG_GRD4a = resample(RNG_GRD4,4000)
Grid: URBG_GRD4a = resample(URBG_GRD4,4000)
Grid: URB_GRD4a = resample(URB_GRD4,4000)
Grid: WATG_GRD4a = resample(WATG_GRD4,4000)
Grid: WETG_GRD4a = resample(WETG_GRD4,4000)

Turn these back into polys

Arc: gridpoly AGG_GRD4A agg_cov
Arc: gridpoly AG_GRD4A ag_cov
Arc: gridpoly BARG_GRD4A barg_cov
Arc: gridpoly DECIDG_GRD4A DECIDG_cov
Arc: gridpoly EVGRG_GRD4A EVGRG_cov
Arc: gridpoly MIXG_GRD4A MIXG_cov
Arc: gridpoly RKYG_GRD4A RKYG_cov
Arc: gridpoly RNGG_GRD4A RNGG_cov
Arc: gridpoly RNG_GRD4A RNG_cov
Arc: gridpoly URBG_GRD4A URBG_cov
Arc: gridpoly URB_GRD4A URB_cov
Arc: gridpoly WATG_GRD4A WATG_cov
Arc: gridpoly WETG_GRD4A WETG_cov

Now alter the grid-code to make them unique.

```
Tables: sel AGG_COV.PAT
611 Records Selected.
Tables: alter grid-code
COLUMN   ITEM NAME       WIDTH OUTPUT  TYPE N.DEC  ALTERNATE NAME
   17  GRID-CODE            4     8     B     -
Item Name: agg
Tables: sel AG_COV.PAT
585 Records Selected.
Tables: alter grid-code
COLUMN   ITEM NAME       WIDTH OUTPUT  TYPE N.DEC  ALTERNATE NAME
   17  GRID-CODE            4     8     B     -
Item Name: ag
Tables: sel BARG_COV.PAT
360 Records Selected.
Tables: alter grid-code
COLUMN   ITEM NAME       WIDTH OUTPUT  TYPE N.DEC  ALTERNATE NAME
   17  GRID-CODE            4     8     B     -
Item Name: barg
Tables: sel DECIDG_COV.PAT
321 Records Selected.
```

```
Tables: alter grid-code
COLUMN   ITEM NAME       WIDTH OUTPUT  TYPE N.DEC  ALTERNATE NAME
   17  GRID-CODE            4     8     B     -
Item Name: decidg
Tables: sel EVGRG_COV.PAT
814 Records Selected.
Tables: alter grid-code
COLUMN   ITEM NAME       WIDTH OUTPUT  TYPE N.DEC  ALTERNATE NAME
   17  GRID-CODE            4     8     B     -
Item Name: evgrg
Tables: sel MIXG_COV.PAT
356 Records Selected.
Tables: alter grid-code
COLUMN   ITEM NAME       WIDTH OUTPUT  TYPE N.DEC  ALTERNATE NAME
   17  GRID-CODE            4     8     B     -
Item Name: mixg
Tables: sel RKYG_COV.PAT
13 Records Selected.
Tables: alter grid-code
COLUMN   ITEM NAME       WIDTH OUTPUT  TYPE N.DEC  ALTERNATE NAME
   17  GRID-CODE            4     8     B     -
Item Name: rkyg
Tables: sel RNGG_COV.PAT
1497 Records Selected.
Tables: alter grid-code
COLUMN   ITEM NAME       WIDTH OUTPUT  TYPE N.DEC  ALTERNATE NAME
   17  GRID-CODE            4     8     B     -
Item Name: rngg
Tables: sel URBG_COV.PAT
448 Records Selected.
Tables: alter grid-code
COLUMN   ITEM NAME       WIDTH OUTPUT  TYPE N.DEC  ALTERNATE NAME
   17  GRID-CODE            4     8     B     -
Item Name: urbg
Tables: sel URB_COV.PAT
484 Records Selected.
Tables: alter grid-code
COLUMN   ITEM NAME       WIDTH OUTPUT  TYPE N.DEC  ALTERNATE NAME
   17  GRID-CODE            4     8     B     -
Item Name: urb
Tables: sel WATG_COV.PAT
310 Records Selected.
Tables: alter grid-code
COLUMN   ITEM NAME       WIDTH OUTPUT  TYPE N.DEC  ALTERNATE NAME
   17  GRID-CODE            4     8     B     -
Item Name: watg
Tables: sel WETG_COV.PAT
283 Records Selected.
Tables: alter grid-code
COLUMN   ITEM NAME       WIDTH OUTPUT  TYPE N.DEC  ALTERNATE NAME
   17  GRID-CODE            4     8     B     -
```

Item Name: wetg

Now do the identities with the 4km coverage. First thing I have to do is finalize the 4km cov.

Workspace: /TRINIDAD/UAM_AERO/WS.UAMAERO

Arc: polygrid AERO_3_FIP fip2km_grd fips
Grid: setcell minof
Grid: fip4km_grd = resample(fip2km_grd,4000)

Results look ok in ap. Need to do some fine tuning at the county boundaries. Will do that in ae.

Arc: gridpoly FIP4KM_GRD FIP4KM_cov
Arc: identity AERO3_4KM FIP4KM_cov AERO3_4KM2

Fixed things in ae; converted grid-code to fips
Final cov is aero3_4km

Now back to identitying the lu covs.

Arc: identity ../AERO3_4KM AGG_COV lu4km1
Arc: identity lu4km1 AG_COV lu4km2
Arc: identity lu4km2 BARG_COV lu4km3
Arc: identity lu4km3 DECIDG_COV lu4km4
Arc: identity lu4km4 EVGRG_COV lu4km5
Arc: identity lu4km5 MIXG_COV lu4km6
Arc: identity lu4km6 RKYG_COV lu4km7
Arc: identity lu4km7 RNGG_COV lu4km8
Arc: identity lu4km8 RNG_COV lu4km
Arc: identity lu4km URBG_COV lu4km9
Arc: identity lu4km9 URB_COV lu4km10
Arc: identity lu4km10 WATG_COV lu4km11
Arc: identity lu4km11 WETG_COV lu4km12

Drop a whole bunch of items from lu4km12

Now I need to implement the cursor aml, but first I need to do a little checking on the final identitied cov to make sure that the whole aml applies.

11/14/00

Things are finished now, with aero_lu_4km being the holder of the 4 km land use. This was finished off with calc3lu.aml. All of the intermeadiate coverages and grids have been deleted. If this needs to be redone, folow the steps in these notes all the way up to this point.

AML'S USED IN CREATION OF LAND USE DATABASE

LU-AREA.AML

```
/* 8/00
/*
/* This calculates the sq km of the land use categories needed for
```

```
/* area source ammonia surrogates
/*PB
/*
/*
&echo &on

&if [exists aero_3_lu2 -cover] &then
      kill aero_3_lu2 all
      copy aero_3_lu aero_3_lu2

   &s cov = aero_3_lu2
    additem %cov%.pat %cov%.pat lu1 4 12 f 3
    additem %cov%.pat %cov%.pat lu2 4 12 f 3
    additem %cov%.pat %cov%.pat lu3 4 12 f 3
    additem %cov%.pat %cov%.pat lu4 4 12 f 3
    additem %cov%.pat %cov%.pat lu5 4 12 f 3
    additem %cov%.pat %cov%.pat lu6 4 12 f 3
    additem %cov%.pat %cov%.pat lu7 4 12 f 3
    additem %cov%.pat %cov%.pat lu8 4 12 f 3
    additem %cov%.pat %cov%.pat lu9 4 12 f 3

ap

&s fil1 = fips
&s unit1 = [open %fil1% 0 -read]

&do n = 1 &to 15
   &type %n%
   &s fip = [read %unit1% readstatus]
   clearsel

   &s lt = 0
   &do t = 1 &to 9
      &s lt = ( %lt% + 1 )
      resel %cov% poly aero-lu = %lt%
```

CALCLU2.AML

```
/*============================DISCLAIMER=============================
/*You may use, copy, modify, merge, distribute, alter, reproduce and/or
/*create derivative works of this AML for your own internal use.  All
/*rights not specifically granted herein are reserved to ESRI.
/*
/*THIS AML IS PROVIDED "AS-IS" WITHOUT WARRANTY OF ANY KIND, EITHER
/*EXPRESS OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
/*WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE,
/*WITH RESPECT TO THE AML.
/*
/*ESRI shall not be liable for any damages under any theory of law
/*related to your use of this AML, even if ESRI is advised of the
/*possibilites of such damage.  This AML is not supported by ESRI.
/*******************************************************************
/* This AML processes a coverage called LANDUSE so
/* The 4 references to LANDUSE need to be changed to
/* the appropriate coverage.
```

```
/* An item called HIGHEST has been added to the PAT to
/* hold the landuse type which is the largest for that cell.
/** HIGHEST will be changed to AERO-LU ** PB 1/2000
/** Coverage LANDUSE will be changed to AERO_LU_COV ** PB 1/00
/*======================================================================
/*
/* calclu2.aml
/* Edited and adapted by P. Barickman
/* in the new millenium 1/2000
/*
/* Designed to put a land use uam-aero based land use classification
/* into each grid cell in the domain.
/*
/************************************************
/*Below are the land use categories being attributed
/*with this aml
/*
 /* 1 = urban
 /* 2 = agriculture
 /* 3 = range
 /* 4 = deciduous
 /* 5 = conifer
 /* 6 = mixed forest
 /* 7 = water
 /* 8 = barren
 /* 9 = non forest wetland
 /* 10 = mixed ag & range
 /* 11 = rocky (low shrub)
/************************************************
&echo &on
&if [exists aero_lu_cov -cover] &then
   kill aero_lu_cov all
copy lu13_cov aero_lu_cov
   /***** add the land use item
additem aero_lu_cov.pat aero_lu_cov.pat aero-lu 2 2 i
/*
ap
clearsel
/***** recalc the -9999 values
resel aero_lu_cov poly ag = -9999
calc aero_lu_cov poly ag = 0
clearsel
resel aero_lu_cov poly rng = -9999
calc aero_lu_cov poly rng = 0
clearsel
resel aero_lu_cov poly urb = -9999
calc aero_lu_cov poly urb = 0
clearsel
resel aero_lu_cov poly agg = -9999
calc aero_lu_cov poly agg = 0
clearsel
resel aero_lu_cov poly barg = -9999
calc aero_lu_cov poly barg = 0
clearsel
resel aero_lu_cov poly decidg = -9999
calc aero_lu_cov poly decidg = 0
```

```
clearsel
resel aero_lu_cov poly evgrg = -9999
calc aero_lu_cov poly evgrg = 0
clearsel
resel aero_lu_cov poly mixg = -9999
calc aero_lu_cov poly mixg = 0
clearsel
resel aero_lu_cov poly rkyg = -9999
calc aero_lu_cov poly rkyg = 0
clearsel
resel aero_lu_cov poly rngg = -9999
calc aero_lu_cov poly rngg = 0
clearsel
resel aero_lu_cov poly urbg = -9999
calc aero_lu_cov poly urbg = 0
clearsel
resel aero_lu_cov poly watg = -9999
calc aero_lu_cov poly watg = 0
clearsel
resel aero_lu_cov poly wetg = -9999
calc aero_lu_cov poly wetg = 0
clearsel
/*
/* Recalculate the AG and Urb items to insure that
/* the AGR/QGET landuse takes precedence over the USGS landuse.
/* The point of the following recalculation is that if a cell has
/* predominantly urban or agricultural character, the classification
/* from usgs should not be allowed to override the class from agrc if
/* it turns out to have a larger sq meters of area.
/* For a cell in which neither of these classes dominate, a simple
/* recalculation of of ag or urb should not change its final
characterization.
/*
/* agriculture

resel aero_lu_cov poly ag > urb
resel aero_lu_cov poly urbg > ag
calc aero_lu_cov poly ag = urbg + 10
clearsel
/*
/* urban

resel aero_lu_cov poly urb > ag
resel aero_lu_cov poly agg > urb
calc aero_lu_cov poly urb = agg + 10
clearsel
/*
/*************** Use CURSORS **********************
reselect aero_lu_cov polygon area > 0

cursor edit declare aero_lu_cov poly rw
cursor edit open

/* Sort all of the item values for each record,
/* and extract element 13 which will be the highest value.

/* The item which holds that highest value will then
```

```
/* be tested for and the appropriate code written to the
/* HIGHEST attribute.
/* HIGHEST changed to AEERO-LU   **PB 1/00

&do &while %:edit.AML$NEXT%

    &s high = [extract 13 [sort %:edit.AG% %:edit.RNG% %:edit.URB%~
                                %:edit.AGG% %:edit.BARG%
%:edit.DECIDG%~
                                %:edit.EVGRG% %:edit.MIXG%
%:edit.RKYG%~
                                %:edit.RNGG% %:edit.URBG% %:edit.WATG%~
                                %:edit.WETG% -numeric]]

    &select %high%
       &when %:edit.AG%
          &s :edit.AERO-LU = 2

       &when %:edit.RNG%
          &s :edit.AERO-LU = 3

       &when %:edit.URB%
          &s :edit.AERO-LU = 1

       &when %:edit.AGG%
          &s :edit.AERO-LU = 2

       &when %:edit.BARG%
          &s :edit.AERO-LU = 8

       &when %:edit.DECIDG%
          &s :edit.AERO-LU = 4

       &when %:edit.EVGRG%
          &s :edit.AERO-LU = 5

       &when %:edit.MIXG%
          &s :edit.AERO-LU = 6

       &when %:edit.RKYG%
          &s :edit.AERO-LU = 11

       &when %:edit.RNGG%
          &s :edit.AERO-LU = 3

       &when %:edit.URBG%
          &s :edit.AERO-LU = 1

       &when %:edit.WATG%
          &s :edit.AERO-LU = 7

       &when %:edit.WETG%
          &s :edit.AERO-LU = 9
    &end

    cursor edit next
&end
```

```
cursor edit close
quit
&echo &off
&return
```

CALCLU3.AML

```
/*===========================DISCLAIMER=============================
/*You may use, copy, modify, merge, distribute, alter, reproduce and/or
/*create derivative works of this AML for your own internal use.  All
/*rights not specifically granted herein are reserved to ESRI.
/*
/*THIS AML IS PROVIDED "AS-IS" WITHOUT WARRANTY OF ANY KIND, EITHER
/*EXPRESS OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
/*WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE,
/*WITH RESPECT TO THE AML.
/*
/*ESRI shall not be liable for any damages under any theory of law
/*related to your use of this AML, even if ESRI is advised of the
/*possibilites of such damage.  This AML is not supported by ESRI.
/*********************************************************************
/* This AML processes a coverage called LANDUSE so
/* The 4 references to LANDUSE need to be changed to
/* the appropriate coverage.

/* An item called HIGHEST has been added to the PAT to
/* hold the landuse type which is the largest for that cell.
/** HIGHEST will be changed to AERO-LU ** PB 1/2000
/** Coverage LANDUSE will be changed to AERO_LU_COV ** PB 1/00
/*=================================================================
/*
/* calclu3.aml
/* Edited and adapted from calclu2.aml by P. Barickman
/*  11/2000
/*
/* Designed to put a land use uam-aero based land use classification
/* into each grid cell in the domain.
/*
/* This is run again on the land use classes on a domain of 4 km cells.
/* The preprocessing to arrive at this step is documented in
notes2.sdw.
/*********************************************
/*Below are the land use categories being attributed
/*with this aml
/*
 /* 1 = urban
 /* 2 = agriculture
 /* 3 = range
 /* 4 = deciduous
 /* 5 = conifer
 /* 6 = mixed forest
 /* 7 = water
 /* 8 = barren
 /* 9 = non forest wetland
```

```
 /* 10 = mixed ag & range
 /* 11 = rocky (low shrub)
/************************************************
&echo &on
&if [exists aero_lu_4km -cover] &then
   kill aero_lu_4km all
copy lu4km12 aero_lu_4km
   /***** add the land use item
additem aero_lu_4km.pat aero_lu_4km.pat aero-lu 2 2 i
/*
ap
clearsel
/*
/* Recalculate the AG and Urb items to insure that
/* the AGR/QGET landuse takes precedence over the USGS landuse.
/* The point of the following recalculation is that if a cell has
/* predominantly urban or agricultural character, the classification
/* from usgs should not be allowed to override the class from agrc if
/* it turns out to have a larger sq meters of area.
/* For a cell in which neither of these classes dominate, a simple
/* recalculation of of ag or urb should not change its final
characterization.
/*
/* agriculture

resel aero_lu_4km poly ag > urb
resel aero_lu_4km poly urbg > ag
calc aero_lu_4km poly ag = urbg + 10
clearsel
/*
/* urban

resel aero_lu_4km poly urb > ag
resel aero_lu_4km poly agg > urb
calc aero_lu_4km poly urb = agg + 10
clearsel
/*
/*************** Use CURSORS **********************
reselect aero_lu_4km polygon area > 0

cursor edit declare aero_lu_4km poly rw
cursor edit open

/* Sort all of the item values for each record,
/* and extract element 13 which will be the highest value.

/* The item which holds that highest value will then
/* be tested for and the appropriate code written to the
/* HIGHEST attribute.
/* HIGHEST changed to AEERO-LU   **PB 1/00

&do &while %:edit.AML$NEXT%

    &s high = [extract 13 [sort %:edit.AG% %:edit.RNG% %:edit.URB%~
                                %:edit.AGG% %:edit.BARG%
%:edit.DECIDG%~
```

```
                                %:edit.EVGRG% %:edit.MIXG%
%:edit.RKYG%~
                                %:edit.RNGG% %:edit.URBG% %:edit.WATG%~
                                %:edit.WETG% -numeric]]

    &select %high%
       &when %:edit.AG%
          &s :edit.AERO-LU = 2

       &when %:edit.RNG%
          &s :edit.AERO-LU = 3

       &when %:edit.URB%
          &s :edit.AERO-LU = 1

       &when %:edit.AGG%
          &s :edit.AERO-LU = 2

       &when %:edit.BARG%
          &s :edit.AERO-LU = 8

       &when %:edit.DECIDG%
          &s :edit.AERO-LU = 4

       &when %:edit.EVGRG%
          &s :edit.AERO-LU = 5

       &when %:edit.MIXG%
          &s :edit.AERO-LU = 6

       &when %:edit.RKYG%
          &s :edit.AERO-LU = 11

       &when %:edit.RNGG%
          &s :edit.AERO-LU = 3

       &when %:edit.URBG%
          &s :edit.AERO-LU = 1

       &when %:edit.WATG%
          &s :edit.AERO-LU = 7

       &when %:edit.WETG%
          &s :edit.AERO-LU = 9
    &end

    cursor edit next
&end

cursor edit close
quit
&echo &off
&return
```

10.1.2 Process Notes for Creating Base Year Gridded Population Surrogate

1/27/00

Creating 2 km gridded population from MPO traffic analysis zones.

Current location: /trinidad/uam_aero/ws.uamaero/ws.pop/shapes

Shape files for WFRC taz and pop have already been converted and are in the coverage:
Workspace: /TRINIDAD/UAM_AERO/WS.UAMAERO/WS.POP/WFRC_96TAZ

Now will convert the shapefiles from MAG. These are the 96 population with updated TAZ boundaries for 2000.

Arc: shapearc taz2000 mag_96taz type
Arc: clean mag_96taz
Arc: regionpoly mag_96taz mag_96taz2 type mag_96taz2.safe
Arc: killem MAG_96TAZ
Arc: rename MAG_96TAZ2 MAG_96TAZ

Drop some items from both of the TAZ coverages now.
Current location: /trinidad/uam_aero/ws.uamaero/ws.pop

join the population to the mag data set

Arc: tables
Enter Command: define mag.join2

Did the define

Enter Command: sel MAG.JOIN2
Enter Command: add from mag96pop.csv
Enter Command: q

2/1/00 Continuing where I left off

Arc: joinitem MAG_96TAZ.PAT MAG.JOIN2 MAG_96TAZ.PAT taz99

Now do a QC to see if things look like they should.

Things are a mess. To fix them I got rid of some sliver polygons. Now I am fixing it this way.

Enter Command: copy MAG.JOIN2 MAG.JOIN3 nodata
Enter Command: sel MAG.JOIN3
Enter Command: add from mag96pop.csv
Enter Command: q

Arc: dropitem MAG_96TAZ.pat MAG_96TAZ.pat Z6_POP
Arc: clean MAG_96TAZ
Arc: joinitem MAG_96TAZ.pat MAG.JOIN3 MAG_96TAZ.pat taz99

Now QC it again. QA carried out. Things look good. The numbers in the TAZ and the total numbers match those in the shape file and the excel file. Now it is on to putting in the population in the outlying counties.

2/2/00

Workspace: /TRINIDAD/UAM_AERO/WS.UAMAERO/WS.POP
Arc: copy ../AERO3_CORP ./AERO3_CORP
Arc: additem AERO3_CORP.pat AERO3_CORP.pat pop96 5 5 i

First thing I will do is to put the population into each town's polygons. Population data comes from GOPB. It is in the file file: /trinidad/uam_aero/ws.uamaero/ws.pop/pop.sdc.
This file was created from data take from:
http://www.governor.state.ut.us/dea/Profiles/Data/data.html. From there go to 1990-1998 City Population Estimates - Data Source: Bureau of the Census.
The process will be to simply select a polygon in ae, find out its name, look up the population from the file and then enter that value in the pop96 item.

Next thing is to grid the population from the WFRC + MAG + the cities. After that is done I have to grid up the population in the outlying counties outside of the town boundaries.

Will grid these up at 25 m resolution to start. These will be huge grids which will be eliminated as they are retired.

First get an item of population per 625 sq m. (25 x 25 meter cell)
Arc: additem MAG_96TAZ.pat MAG_96TAZ.pat pop625sqm 8 8 f 3
Arc: additem WFRC_96TAZ.pat WFRC_96TAZ.pat pop625sqm 8 8 f 3
Arc: additem AERO3_CORP.pat AERO3_CORP.pat pop625sqm 8 8 f 3

Arc: tables
Enter Command: sel MAG_96TAZ.pat
Enter Command: calc pop625sqm = z6_pop / (area / 625)
Enter Command: sel WFRC_96TAZ.pat
Enter Command: calc pop625sqm = Z6__POP / (area / 625)
Enter Command: sel AERO3_CORP.pat
Enter Command: calc pop625sqm = POP96 / (area / 625)
Did a QA check and this method looks fine.
Now Grid these up
Arc: polygrid MAG_96TAZ mag25m_grd POP625SQM
Cell Size (square cell): 25
Arc: polygrid WFRC_96TAZ wfrc25m_grd POP625SQM
Cell Size (square cell): 25
Arc: polygrid AERO3_CORP corp25m_grd POP625SQM
Cell Size (square cell): 25

Go into grid; sum up and resample to 2km. Instead of a block sum on this one I will use a zonal sum so that I sum things up in the aero 2km cells (they will be the zones).

Create a zone grid
Arc: polygrid POP96_2KM zone_2km cell-id
Cell Size (square cell): 2000

Number of Rows   = 113
Number of Columns = 67
grid
Grid: setcell minof
Grid: CORP25M_sum = zonalsum (ZONE_2KM,CORP25M_GRD)
Grid: MAG25M_sum = zonalsum (ZONE_2KM,MAG25M_GRD)
Grid: WFRC25M_SUM = zonalsum(ZONE_2KM,WFRC25M_GRD)
Now resample
Grid: CORP25M_rsmp = resample (CORP 25M_SUM,2000)
Grid: WFRC25M_rsmp = resample (WFRC25M_SUM,2000)
Grid: MAG25M_rsmp = resample (MAG25M_SUM,2000)
Due QA. So far looks real good. Looked at the 6 cells containing Morgan city and the pop values came out almost exactly to the GOPB data for Morgan.

Grid: CORP25M_int = int(CORP25M_RSMP)
Grid: MAG25M_int = int(MAG25M_RSMP)
Grid: WFRC25M_int = int(WFRC25M_RSMP)

Grid: corp2km_pop = gridpoly(CORP25M_INT)
Grid: mag2km_pop = gridpoly(MAG25M_INT)
Grid: wfrc2km_POP = GRIdpoly(WFRC25M_INT)
q
QA was done and things still look right. One or two more steps left.

Arc: copy ../AERO3_2KM ./pop96_2km

Arc: identity POP96_2KM CORP2KM_POP aPOP96_2KM
ae;ec aPOP96_2KM ;ef poly;de poly;bc AERO3_CORP 6;be arc;draw
Arcedit: sel all
Arcedit: resel grid-code = -9999
Arcedit: calc grid-code = 0
Did a QA selection and these look quite close - the differences are in rounding errors.

Enter Command: sel APOP96_2KM.pat
Enter Command: alter grid-code
Item Name: outlypop

2/3/00

Had some problems with mag and wfrc data. Believe have them fixed. The methods above work to this point.

Arc: identity POP96_2KM MAG2KM_POP bPOP96_2KM
Arc: ae;ec BPOP96_2KM;ef poly;de poly;bc MAG_96TAZ 6;be arc;draw
Arcedit: sel all
Arcedit: resel grid-code = -9999
Arcedit: calc grid-code = 0
Arcedit: save
Arcedit: q
Do a QA in ap to see if the gridded population matches the TAZ polygon population.

Record FREQUENCY SUM-Z6_POP
1 344 321086.000000
Record FREQUENCY SUM-GRID-CODE
1 903 319945.000000
This is less than 1% off for the total Utah county pop. Sample at the TAZ level in ae using a somewhat coarse method of getting the population of 1 grid cell then comparing that to the population in th TAZ which are included in the grid cell. This looks right. It is not exact because some of the TAZ polys are outside of the grid cell, but by doing a visual guess at the area outside the cell and the difference in population it looks right.

Arc: identity POP96_2KM WFRC2KM_POP cPOP96_2KM
Arc: ae;ec cPOP96_2KM;ef poly;de poly;bc WFRC_96TAZ 6;be arc;draw
Arcedit: sel all
Arcedit: resel grid-code = -9999
Arcedit: calc grid-code = 0
Arcedit: save

Complete the QA

Record FREQUENCY SUM-GRID-CODE
1 548 1240035.000000
Record FREQUENCY SUM-Z6__POP
1 704 1240432.000000

Excellent match for the total. One cell looks good too. So now on to the final steps.

Enter Command: sel BPOP96_2KM.pat
Enter Command: alter grid-code
Item Name: magpop
Enter Command: sel CPOP96_2KM.pat
Enter Command: alter grid-code
Item Name: wfrcpop

Now identity each of these with POP96_2KM to get the final cell-based population coverage.

Arc: identity POP96_2KM APOP96_2KM POP96_2KM2
Arc: identity POP96_2KM2 BPOP96_2KM POP96_2KM3
Arc: identity POP96_2KM3 CPOP96_2KM POP96_2KM4

Now drop all of the superfluous items
Check to be sure that if one of the 3 pop items has a value in it, the other 2 contain 0's.
There is are a dozen or so that overlap, but that should be along the border and that should be ok.

Before I combine these I am going to factor them so that the numbers from each data set match exactly (in total) to this final coverage.

Outlying pop is only off by 88. I am leaving it.

Enter Command: sel MAG_96TAZ.PAT
Record FREQUENCY SUM-Z6_POP
1 363 321086.000000

Enter Command: sel POP96_2KM4.PAT
Record FREQUENCY SUM-MAGPOP
1 903 319945.000000
Enter Command: calc magpop = magpop * (321086 / 319945)
Record FREQUENCY SUM-MAGPOP
1 903 320968.000000

Enter Command: sel WFRC_96TAZ.PAT
Record FREQUENCY SUM-Z6__POP
1 752 1240432.000000
Enter Command: sel POP96_2KM4.PAT
Enter Command: resel wfrcpop > 0
Record FREQUENCY SUM-WFRCPOP
1 548 1240035.000000
CLOSE ENOUGH!

Arc: additem POP96_2KM4.pat POP96_2KM4.pat pop96 4 8 b

Enter Command: sel POP96_2KM4.pat
Enter Command: calc pop96 = OUTLYPOP + MAGPOP + WFRCPOP

Record FREQUENCY SUM-POP96
1 7572 1642574.000000

81659 + 321086 + 1240432 = 1643177

Close enough!

Now get rid of all of the intermediate coverages and grids.

Arc: rename POP96_2KM4 POP96_2KM

Still need to get the remainder populations in each county distributed into the grid cells.

The method is going to be this:

From the GOPB data, proprortion the "balance of county" population by the land area of the county inside the domain. For example, Box Elder has 22% of it's land area in the domain. Its balance of population is 7,887. So, 7887 * .22 = 1,735. Those get evenly divided in cells outside the town.

Additional cells in each county which will not receive population will be those in the lake and those above 6,500 feet (1,981 meters) elevation.

Here we go

Arc: copy POP96_2KM bal_pop
Drop extra items
Arc: copy ../ELEV_2KM ./elev_65
$$

Change of plans here. The eastern counties have most of there area above 6,500. So I reselected on the eastern counties and then deleted cells < 7,500 ft. This will be my erase coverage for elevation.
Arcedit: additem elev 1 1 i
Arcedit: sel all
Arcedit: calc elev = 1
Arc: additem BAL_POP.pat BAL_POP.pat outlybal 4 8 b
Arc: additem BAL_POP.pat BAL_POP.pat lake 1 1 i

I am going to overlay the lake and put in the lake cells by hand. Included Promontory Pt. As a masked out area for population.

Arc: identity BAL_POP ELEV_65 BAL_POP2

This looks good I have an elev = 1 in just the cells that they should be.

Arc: identity BAL_POP2 POP96_2KM BAL_POP3

Look at it in ae ; see if it looks right. Looks good.

Now get rid of all the items in BAL_POP3 except lake , elev, and outlypop. These will be the ones where population does not go.

Now put the remainder population in bal_pop3

Arc: ae;ec BAL_POP3;ef poly;de poly;draw
Arcedit: sel fips = 3
970 element(s) now selected
Arcedit: resel lake = 0 and elev = 0 and outlypop = 0
339 element(s) now selected
Arcedit: calc OUTLYBAL = 1748 / 339

Arcedit: sel fips = 5
313 element(s) now selected
Arcedit: resel lake = 0 and elev = 0 and outlypop = 0
173 element(s) now selected
Arcedit: calc OUTLYBAL = 2357 / 173

Arcedit: sel fips = 23
698 element(s) now selected
Arcedit: resel lake = 0 and elev = 0 and outlypop = 0
562 element(s) now selected
Not gonna waste my time since the balance pop is only 267

Arcedit: sel fips = 29
388 element(s) now selected
Arcedit: resel lake = 0 and elev = 0 and outlypop = 0
272 element(s) now selected
Arcedit: calc OUTLYBAL = 4378 / 272

Arcedit: sel fips = 33
205 element(s) now selected
Arcedit: resel lake = 0 and elev = 0 and outlypop = 0
127 element(s) now selected
Arcedit: calc OUTLYBAL = 198 / 127

Arcedit: sel fips = 39
153 element(s) now selected
Arcedit: resel lake = 0 and elev = 0 and outlypop = 0
80 element(s) now selected
Arcedit: calc OUTLYBAL = 414 / 80

Arcedit: sel fips = 43
390 element(s) now selected
Arcedit: resel lake = 0 and elev = 0 and outlypop = 0
302 element(s) now selected
Arcedit: calc OUTLYBAL = 4463 / 302

Arcedit: sel fips = 45
1494 element(s) now selected
Arcedit: resel lake = 0 and elev = 0 and outlypop = 0
1148 element(s) now selected
Arcedit: calc OUTLYBAL = 2416 / 1148

Arcedit: sel fips = 51
286 element(s) now selected
Arcedit: resel lake = 0 and elev = 0 and outlypop = 0
141 element(s) now selected
Arcedit: calc OUTLYBAL = 1463 / 141
Arcedit: save

Make the final final cov.
Arc: identity POP96_2KM BAL_POP3 POP96_2KM2
Drop items
Enter Command: sel POP96_2KM2.pat
Enter Command: calc pop96 = pop96 + outlybal
Record FREQUENCY SUM-POP96
1 7572 1659331.000000
This looks right. Close enough anyway. It added about another 17 or 18 K.

Kill the unneeded covs.
Arc: rename POP96_2KM2 POP96_2KM

2/4/00

Have some population in the lake in Tooele Co. Need to get it out. Going to do it by hand.
Reselect the cells in the lake count up how much pop is in there. Probably less than 100, I would bet. Will calc those values to 0 and then divide that pop into the other cells in Tooele.

Arc: ae;ec POP96_2KM;ef poly;de poly;draw
Arcedit: bc ../LAKES_3 6;be arc;draw
Arcedit: bc ../STATE_CLP3 4;draw
Arcedit: asel many
Statistics: end
Record FREQUENCY SUM-OUTLYBAL
1 220 356.000000

Arcedit: calc OUTLYBAL = 0
Arcedit: calc pop96 = 0
Arcedit: sel fips = 45
1494 element(s) now selected
Arcedit: resel outlybal > 0
970 element(s) now selected
Record FREQUENCY SUM-OUTLYBAL
1 970 1940.000000
calc outlybal = (outlybal + (356 / 970))
Do you want to use them (Y/N)? y
Record FREQUENCY SUM-OUTLYBAL
1 970 1940.000000

Didn't change the totals because of the rounding. Just as well.

Arcedit: save
Arcedit: q

Process for 1996 completed.

10.1.3 Process Notes for Creating Base Year Gridded Mobile Emissions Surrogates

5/17/00

Gridding up mobile emissions. Start with the outlying counties and first grid up the vmt surrogates by facility type (FC).

Spatial surrogate codes, which I will create for mobile

10 local
20 freeway
30 ramp
40 arterial
41 rural arterial

The rural arterial is a separate surrogate because of the way vmt is reported by UDOT for the outlying counties. It is both put on a network and additional vmt is reported in the towns and outlying parts of the county.

In a sense what this rural arterial surrogate does is replace the ramp surrogate in the urban areas.

Workspace: /TRINIDAD/UAM_AERO/WS.UAMAERO/WS.MOBILE

Arc: copy UDOT_AERO outly_udot

Now get rid of the roads in the 4 WF counties.
Done in AE.

Arc: clip OUTLY_UDOT ../state_clp3 OUTLY_UDOT2 line
Arc: additem OUTLY_UDOT2.AAT OUTLY_UDOT2.AAT oldlength 4 12 f 3

Tables: sel OUTLY_UDOT2.AAT

274 Records Selected.
Tables: calc oldlength = length
Tables: q

Arc: additem OUTLY_UDOT2.AAT OUTLY_UDOT2.AAT wdvmt2 8 10 F 0
Arc: additem OUTLY_UDOT2.AAT OUTLY_UDOT2.AAT wevmt2 8 10 F 0

5/19/00

Takin' a break here from the outlying data and going back to the 4 county wf area.

Converted the shape files into wf_artfre for aterials and freeways. Going to remove all of the superfluous items and create a classification item based on free flow speed, since I can see what that is but don't see a functional class item. Also removed all of the local road links. These are at speed of 20 mph.
Did lots of stuff, now I am going to create a vmt-by-roadclass surrogate.

Arcedit: show ec
/TRINIDAD/UAM_AERO/WS.UAMAERO/WS.MOBILE/WF_ARTFRE
Arcedit: sel all
Arcedit: calc vmtday = (distance * DAILY_VOL)
Arcedit: calc vmtsum = (distance * SUM_4PDVOL)
Arcedit: save

Prepare to identity the mobile coverage
Arc: additem WF_ARTFRE.aat WF_ARTFRE.aat oldlength 4 12 f 3
Tables: calc oldlength = length

Now Identity this one plus the outylying UDOT line work.

Arc: identity WF_ARTFRE ../AERO_3_fip WF_ARTFRE2 line
Arc: identity OUTLY_UDOT2 ../AERO_3_fip OUTLY_UDOT3 line
Recalculate the vmt based on new link lengths from the identitied cell boundaries
Arc: additem WF_ARTFRE2.aat WF_ARTFRE2.aat VMTDAY2 4 12 F 3
Arc: additem WF_ARTFRE2.aat WF_ARTFRE2.aat VMTsum2 4 12 f 3

Tables: sel WF_ARTFRE2.aat
Tables: calc VMTDAY2 = (vmtday * (length / oldlength))
Tables: calc vmtsum2 = (vmtsum * (length / oldlength))

QA

Tables: statistics

Enter statistical expressions. Type END or blank line to end.
Statistics: sum VMTDAY2
Statistics: sum vmtsum2
Statistics: end
Record FREQUENCY SUM-VMTDAY2 SUM-VMTSUM2
1 13210 31792924.590140 32105203.425211
Tables: sel wf_artfre.aat

10219 Records Selected.
Tables: statistics

Enter statistical expressions. Type END or blank line to end.
Statistics: sum vmtday
Statistics: sum vmtsum
Statistics: end
Record FREQUENCY SUM-VMTDAY SUM-VMTSUM
1 10219 31790301.645160 32102139.046647

Looks good, real good.

Now for the outlying counties

Arc: tables
Copyright (C) 1982-1999 Environmental Systems Research Institute, Inc.
All rights reserved.
TABLES Version 8.0.1 (Fri Dec 3 10:45:59 PST 1999)

Tables: sel OUTLY_UDOT3.aat
972 Records Selected.
Tables: calc WDVMT = (WDVMT * (length / oldlength))
Tables: calc WEVMT = (WEVMT * (length / oldlength))
Tables: calc VMT = (VMT * (length / oldlength))
Tables: statistics
QA
Enter statistical expressions. Type END or blank line to end.
Statistics: sum WDVMT
Statistics: sum WEVMT
Statistics: sum VMT
Statistics: end
Record FREQUENCY SUM-WDVMT SUM-WEVMT SUM-VMT
1 972 3662164.956077 3785967.993834 4632908.221970
Tables: sel OUTLY_UDOT2.aat
274 Records Selected.
Tables: statistics

Enter statistical expressions. Type END or blank line to end.
Statistics: sum WDVMT
Statistics: sum WEVMT
Statistics: sum VMT
Statistics: end
Record FREQUENCY SUM-WDVMT SUM-WEVMT SUM-VMT
1 274 3662164.000000 3785967.000000 4632907.000000

Looks good again.

Now I want to get these values into the domain grid.

Arc: copy ../AERO_3_FIP ./mob_vmt_3

I think I need to stop right here and wait until I get my emissions data. I think I really want to step back to the point before I identitied the line coverages and put my emissions by pollutant by vehicle-type by road class into the coverage. Then identity it and sum up my matrix of emissions.

One thing I will do right now is to create better items for selecting by facility class.

First, kill my identity covs. I will recreate them later when I have the emissions in.

5/26/00

vmt for the outlying counties by road class. FC 1 = freeway, FC 2 = arterial

Arcedit: sel county = 3
Arcedit: resel fc = 1
14 element(s) now selected

Record	FREQUENCY	SUM-WDVMT	SUM-WEVMT	SUM-VMT
1	14	516974.000000	570689.000000	671391.000000

Arcedit: sel county = 3
59 element(s) now selected
Arcedit: resel fc = 2
45 element(s) now selected

Record	FREQUENCY	SUM-WDVMT	SUM-WEVMT	SUM-VMT
1	45	428228.000000	386018.000000	499482.000000

Arcedit: sel county = 5
30 element(s) now selected
Arcedit: resel fc = 1
0 element(s) now selected
Arcedit: sel county = 5
30 element(s) now selected
Arcedit: resel fc = 2
30 element(s) now selected

Record	FREQUENCY	SUM-WDVMT	SUM-WEVMT	SUM-VMT
1	30	226901.000000	215267.000000	275802.000000

Arcedit: sel county = 23
29 element(s) now selected
Arcedit: resel fc = 1
6 element(s) now selected

Record	FREQUENCY	SUM-WDVMT	SUM-WEVMT	SUM-VMT
1	6	318843.000000	351976.000000	414095.000000

Arcedit: sel county = 23
29 element(s) now selected
Arcedit: resel fc = 2

23 element(s) now selected

Record	FREQUENCY	SUM-WDVMT	SUM-WEVMT	SUM-VMT
1	23	133236.000000	134930.000000	170804.000000

Arcedit: sel county = 29
22 element(s) now selected
Arcedit: resel fc = 1
10 element(s) now selected

Record	FREQUENCY	SUM-WDVMT	SUM-WEVMT	SUM-VMT
1	10	146012.000000	161186.000000	189631.000000

Arcedit: sel county = 29
22 element(s) now selected
Arcedit: resel fc = 2
11 element(s) now selected

Record	FREQUENCY	SUM-WDVMT	SUM-WEVMT	SUM-VMT
1	11	27188.000000	27540.000000	34859.000000

Arcedit: sel county = 29
22 element(s) now selected
Arcedit: resel fc = 3
1 element(s) now selected

Record	FREQUENCY	SUM-WDVMT	SUM-WEVMT	SUM-VMT
1	1	55.000000	57.000000	70.000000

Arcedit: sel county = 33
2 element(s) now selected
Arcedit: list fc

Record	FC
76	2
80	2

Record	FREQUENCY	SUM-WDVMT	SUM-WEVMT	SUM-VMT
1	2	6241.000000	6316.000000	7997.000000

Arcedit: sel county = 39
8 element(s) now selected
Arcedit: resel fc = 2

Record	FREQUENCY	SUM-WDVMT	SUM-WEVMT	SUM-VMT
1	8	59532.000000	60285.000000	76319.000000

Arcedit: sel county = 43
61 element(s) now selected
Arcedit: resel fc = 1
18 element(s) now selected

Record	FREQUENCY	SUM-WDVMT	SUM-WEVMT	SUM-VMT
1	18	552161.000000	609544.000000	717097.000000

Arcedit: sel county = 43
61 element(s) now selected
Arcedit: resel fc = 2
41 element(s) now selected

Record	FREQUENCY	SUM-WDVMT	SUM-WEVMT	SUM-VMT
1	41	271294.000000	274779.000000	347817.000000

Arcedit: sel county = 43
61 element(s) now selected
Arcedit: resel fc = 3
2 element(s) now selected

Record	FREQUENCY	SUM-WDVMT	SUM-WEVMT	SUM-VMT
1	2	1796.000000	1865.000000	2303.000000

Arcedit: sel county = 45
39 element(s) now selected
Arcedit: resel fc = 1
7 element(s) now selected

Record	FREQUENCY	SUM-WDVMT	SUM-WEVMT	SUM-VMT
1	7	287174.000000	317021.000000	372957.000000

Arcedit: sel county = 45
39 element(s) now selected
Arcedit: resel fc = 2
32 element(s) now selected

Record	FREQUENCY	SUM-WDVMT	SUM-WEVMT	SUM-VMT
1	32	369136.000000	347019.000000	445364.000000

Arcedit: sel county = 51
24 element(s) now selected
Arcedit: resel fc = 2
23 element(s) now selected

Record	FREQUENCY	SUM-WDVMT	SUM-WEVMT	SUM-VMT
1	23	317162.000000	321235.000000	406623.000000

Arcedit: sel county = 51
24 element(s) now selected
Arcedit: resel fc = 3
1 element(s) now selected

Record	FREQUENCY	SUM-WDVMT	SUM-WEVMT	SUM-VMT
1	1	231.000000	240.000000	296.000000

6/5/00

After many days I am back to this process. It looks to me like I have the arterial, freeway and ramp data done by cell for the WF counties. Still need to identity the outlying counties, do a QA on both.

Creating the cell-id'd vmt for the outlying counties is done and documented in id-vmt.aml.

Percentages by-county of vmt for arterial and freeway is now done; method documented in "id-vmt.aml".

"FT" in wf_artfre2 is:

- 0 = local or centroid connector
- 1 = freeway and expressway
- 2 - 6 = various arterials
- 7 = ramps

Need to fill in I80 from Parleys to Summit county line. Will do this in AE by filling in bogus lines, grid cell boundary to grid cell boundary following the I80 line in the UDOT cov. Then I will find out the vmt as given by UDOT for those segements and attribute the data accordingly.

To get the vmt on those links
copy WF_ARTFRE2 to WF_ARTFRE2 a
Record FREQUENCY SUM-VMT
1 6 389979.000000
Arcedit: ec WF_ARTFRE2A;ef arc;draw
The edit coverage is now
/TRINIDAD/UAM_AERO/WS.UAMAERO/WS.MOBILE/WF_ARTFRE2A
13221 element(s) for edit feature ARC
Coverage has no COGO attributes
Arcedit: sel ft = 99
Arcedit: calc vmtday2 = (length / 14861) * 389979
Now I have vmt on each section of I 80 in the east county.
Arcedit: calc ft = 1
Now adapt that aml to put the percentages into the WF counties. Documented in id-vmt2.aml

QA looks good in that the percentage values add to 1 for a given county. The vmt numbers for the coverages were QA'd up on page 3 of these notes. In the outlying counties the total vmt for each county sums up between outly_udot2 vmt and outly_udot3 vmt2 and the percentages add up to 1.

6/6/00

Done with the WF counties. Next thing to do now is to get the local vmt surrogates using population density for the WF counties, based on TAZ boundaries and put the local vmt in the corporate boundaries in the outlying counties.

For the local surrogates I don't even need vmt. I just need population % of the cell that is in the whole county.

Workspace: /TRINIDAD/UAM_AERO/WS.UAMAERO/WS.MOBILE

Arc: copy ../ws.pop/POP96_2KM wf_loc

Drop some superfluous items

Do an aml, all-loc.aml, to get the local percentages for the WF counties and the outlying counties. The logic for this process will be apparent in this aml. Also surrogates for arterial vmt, rural arterial, not on the outlying county network will also be classed in this process.

There are two sets of vmt data for the outlying counties. One is the link based vmt from the A/I coverage, UDOT_AERO. The other is in the spreadsheet, aqsipcnty.xls. This is the vmt by city and the vmt outside the city but inside the county and not on the network. These two data sets will be combined into a spreadsheet called outlyvmt.sdc. It will have the totals of these two data sets for each county and will be used to calculate the mobile emissions from the factors developed with part5 and mobile5.

Since I have already taken into account the population in the towns and outlying areas of the counties when I did the original population gridding I am going to distribute these emissions by pop density just as I did with the WF counties. The pop gridding process is detailed in notes.sdw in ws.pop.

In doing this gridding I will put even some more vmt in cells that have the road network going through them. It is not worth the effort to avoid those cells for the following reasons:

The fraction of total mobile emissions contained in these counties is miniscule compared to the entire domain.

We don't *really* know where these vmt are located in the county anyway. Population density gets at the town based vmt well. The outlying vmt is a large part of this second set of numbers. It will be spread around the county based on population and putting some small percent more vmt on then network cells will be meaningless in the overall scheme of things.

Did it. QA looks good.

Now copy these mobile surrogate files into ws.surrogates, finish the dump surrogates and sew them all together over there.

Arc: copy ALL_LOC ../ws.surrogate/ALL_LOCAL
Arc: copy WF_ARTFRE3 ../ws.surrogate/WF_ARTFRE3
Arc: copy OUTLY_UDOT3 ../ws.surrogate/OUTLY_UDOT3

Done with the mobile part for now. 6/7/00
Need to do some frequency queries on artfre3 and udot3 to get the right values in the final surrogate file.

6/12/00

I Found out that there are some more vmt that need to be added to Weber Co. The method for local still needs to be determined, however, for arterial I will make a separate cov of just the outlying arterials from udot. ID this vmt with the rural arterial surrogate and keep track of the emissions somewhat separately. This meaning(lessness) of the previous statement will become known shortly.

Arc: ae;ec UDOT_AERO;ef arc;de arc;draw
Arcedit: sel webart = 1;draws

13 element(s) now selected
Arcedit: put web_art
Arcedit: q

Arc: additem WEB_ART.aat WEB_ART.aat vmt2 4 12 f 3
Arc: additem WEB_ART.aat WEB_ART.aat per42 4 12 f 7   (per42 = percent of surr. # 42)

Arc: identity WEB_ART MOB_VMT_3 WEB_ART2 line
Tables: sel WEB_ART2.aat
Tables: calc vmt2 = vmt * (length / oldlength)
Statistics: sum vmt2
Statistics: end
Record FREQUENCY   SUM-VMT2
    1   76   108102.365506
Tables: calc per42 = vmt2 / 108102

QA
Statistics: sum per42
Statistics: end
Record FREQUENCY   SUM-PER42
    1   76   1.000003
          Looks good.

AML'S USED TO PROCESS THE MOBILE VMT SURROGATES

ID-VMT2.AML

```
/* 6/5/00
/* id-vmt2.aml
/* Calculates the % of a counties vmt-by-road class for each cell
/*
&echo &on

&if [exists wf_artfre3 -cover] &then
   kill wf_artfre3 all
copy ws.covs/wf_artfre2a wf_artfre3
&s cov = wf_artfre3
additem %cov%.aat %cov%.aat perft1 4 12 f 7
additem %cov%.aat %cov%.aat perft2 4 12 f 7
additem %cov%.aat %cov%.aat perft7 4 12 f 7
additem %cov%.aat %cov%.aat surrogate 2 2 i

/* There are 2 different items in the coverage of calculated vmt/day.
/* Those are vmtday and vmtsum.  Each are calculated by multiplying
distance
/* times daily_vol for vmtday or sum_4pdvol for vmtsum.  To get the % I
/* am going to use just one, that is vmtday.  I assume they should both
/* give me similar % of daily vmt for a link.

ap
clearsel

&s fil1 = wffip
&s unit1 = [open %fil1% 0 -read]
```

```
&do n = 1 &to 4
   &type %n%
   &s fip = [read %unit1% readstatus]
   clearsel
   resel %cov% line fips = %fip%

/* ft = 1
   resel %cov% line ft = 1
      &s t1 = [extract 1 [show select %cov% line]]
         &if %t1% = 0 &then
         &goto jump1
   statistics %cov% line
   sum vmtday2
   end
   [unquote '']

   &s ft1 = [show statistic 1 1]

   calc %cov% line perft1 = vmtday2 / %ft1%
   calc %cov% line surrogate = 20
         &label jump1     /* jumped over a 0 reselect

   clearsel

/* ft = 2
   resel %cov% line fips = %fip%
   resel %cov% line ft = 2 or ft = 3 or ft = 4 or ft = 5 or ft = 6
      &s t1 = [extract 1 [show select %cov% line]]
         &if %t1% = 0 &then
         &goto jump1
   statistics %cov% line
   sum vmtday2
   end
   [unquote '']

   &s ft2 = [show statistic 1 1]

   calc %cov% line perft2 = vmtday2 / %ft2%
   calc %cov% line surrogate = 40
         &label jump1     /* jumped over a 0 reselect

   clearsel

/* ft = 7
   resel %cov% line fips = %fip%
   resel %cov% line ft = 7
      &s t1 = [extract 1 [show select %cov% line]]
         &if %t1% = 0 &then
         &goto jump1
   statistics %cov% line
   sum vmtday2
   end
   [unquote '']

   &s ft7 = [show statistic 1 1]

   calc %cov% line perft7 = vmtday2 / %ft7%
```

```
   calc %cov% line surrogate = 30
         &label jump1     /* jumped over a 0 reselect

   clearsel

&end

&s close = [close %unit1%]
&echo &off
q
&return
```

ALL-LOC.AML

```
/* 6/5/00
/* wf-loc.aml
/* Calculates the % of a counties local vmt for each cell
/*
&echo &on

&if [exists all_local -cover] &then
   kill all_local all
copy ../ws.pop/pop96_2km all_local
&s cov = all_local
additem %cov%.pat %cov%.pat perloc 4 12 f 7
additem %cov%.pat %cov%.pat perartrural 4 12 f 7
additem %cov%.pat %cov%.pat surrogate 2 2 i
additem %cov%.pat %cov%.pat surrogate2 2 2 i
/*
/* surrogate2 is an item to attribute the rural arterial ssc code
ap
clearsel

&s fil1 = wffip
&s unit1 = [open %fil1% 0 -read]

&do n = 1 &to 4              /* WF counties
   &type %n%
   &s fip = [read %unit1% readstatus]
   clearsel
   resel %cov% poly fips = %fip%

   statistics %cov% poly
   sum pop96
   end
   [unquote '']

   &s loc = [show statistic 1 1]

   calc %cov% poly perloc = pop96 / %loc%
   calc %cov% poly surrogate = 10
   clearsel
&end

&s fil2 = outfip
&s unit2 = [open %fil2% 0 -read]
```

```
&do s = 1 &to 9           /* outlying, including rural arterial
   &type %s%
   &s fip = [read %unit2% readstatus]
   clearsel
   resel %cov% poly fips = %fip%

   statistics %cov% poly
   sum pop96
   end
   [unquote '']

   &s locrur = [show statistic 1 1]

   calc %cov% poly perloc = pop96 / %locrur%
   calc %cov% poly perartrural = pop96 / %locrur%
   calc %cov% poly surrogate = 10
   calc %cov% poly surrogate2 = 41

   clearsel
&end /* end s

&s close = [close -all]
&echo &off
q
&return
```

10.1.4 Process for Creating the Final Emission Surrogates

4/27/00

Bring the population and landuse coverages in here and create a coverage of surrogates based on the surrogate file in the smoke data directory.

Arc: copy AERO_3_LU ../ws.surrogate/AERO_3_LU
Arc: copy POP96_2KM ../ws.surrogate/POP96_2KM

Here are the surrogates I need to create for a surrogate cov

SSC Description
50 Population
51 Housing
52 Inverse Housing
53 Inverse Population
54 Rural
55 Urban
60 Area
61 Forest
62 Agriculture
63 Water
64 Rural Forest
65 Urban Forest
71 Airports

72 Highways
73 Ports
74 Railroads
Next 2 are added by me
80 POTW
81 Land fills

I think the first thing I will do to create some new items in AERO_3_LU that match some of the above and recalculate the other lu items to map them to these new items.

Going to be a bit more involved than I thought to get some good surrogates. Here I go.

Current location: /trinidad/uam_aero/ws.uamaero/ws.lu/ws.work_covs
Arc: copy DOM2K_GRD ../../ws.surrogate/DOM2K_GRD
Arc: copy GWALU_GRD ../../ws.surrogate/GWALU_GRD

gwalu_grd is the qget grid of landuse at 30 meters. Here are the items in the grid. The lucode I added in ws.lu to create my first landuse grid for the roughness and depostion factors.

Arc: list GWALU_GRD.vat

Record	VALUE	COUNT	DESCRIPTION	LUCODE
1	0	10565809	No Data	0
2	1	3823306	USFS	0
3	2	2531663	BLM	0
4	3	622098	State of Utah	0
5	6	356990	Military	0
6	7	1058	National Park/Monument	0
7	8	237209	Utah State Parks and Rec.	0
8	9	487359	State Wildlife Management	0
9	11	115272	National Wildlife refuge	0
10	12	429719	Wilderness	0
11	13	97515	Federal Grasslands	3
12	39	3493571	Water Bodies	0
13	40	1644	Intermittent Water Bodies	0
14	101	929568	R1 - Single Family	1
15	102	12522	R2 - 2-4 Units	1
16	103	17232	R3 - Multi-family	1
17	104	10544	R4 - Mobile Homes	1
18	105	555	R5 - Group Quarters	1
19	106	99908	C1 - Retail	1
20	107	110566	C2 - Industrial	1
21	108	8224	C3 - Warehouse	1
22	109	2720	C4 - Office	1
23	110	207189	C5 - Special Purpose	1
24	111	474138	Exempt	0
25	112	939118	Agriculture	2
26	113	1281149	Vacant	0
27	119	28969	Parks / Open Space	3
28	212	865951	Irrigated Cropland	2

Get rid of the dom2k_grd zone grid as it is too large. Going to use AERO_3_LU as the zone grid.
Grid: kill DOM2K_GRD all
Grid: aerozone = polygrid(AERO_3_LU,cell-id,#,#,2000)

5/12/00

Before I go any farther I am going to get the old railroad coverage from the O_3 UAM and the most current mobile line coverages and bring them into this workspace; since they are also part of the surrogates. This is also going to mean a little detour while I create the coverages of roads from UDOT given to me for this study.

From what I can tell at this point the only updated line files that I have for road networks is from UDOT in /TRINIDAD/UAM_AERO/WS.UAMAERO/WS.MOBILE. Those are shapefiles called vmt96 which I am now going to convert.

Current location: /trinidad/uam_aero/ws.uamaero/ws.mobile
Arc: shapearc vmt96 udot_aero
Check it out in AE see what it looks like
Looks good.
Arc: copy UDOT_AERO ../ws.surrogate/UDOT_AERO
This looks good. I will be able to use it for the highways surrogate for the surrogate cov. Won't need any other line coverage for roads for this one.

5/15/00

Don't have the railroad data at this point, unfortunately. So, I will proceed with the others and add the railroads when I get it.
To get a handle on this I am going to start by going down the list. First is population, scc = 50.

Create the first SCC cov.
Arc: copy ../AERO3_2KM ./scc_cov1

Arc: tables
Tables: copy POP96_2KM.pat pop.join
Drop the unnecessary items
Arc: items pop.join
COLUMN ITEM NAME WIDTH OUTPUT TYPE N.DEC ALTERNATE NAME INDEXED?
1 CELL-ID 4 5 B - -
5 POP96 4 8 B - -

Arc: joinitem SCC_COV1.pat pop.join SCC_COV1.pat cell-id

Now for housing, 51, a completely different animal.

Gonna do this in GRID the following way.

Grid: housegrid = select(GWALU_GRD, 'value > 100 and value < 106')
Now I have a 30 m grid of all housing. Now do a zonal sum to get my housing surrogate.
Grid: list housegrid.vat

Record	VALUE	COUNT
1	101	929568
2	102	12522
3	103	17232
4	104	10544
5	105	555

Grid: calc housegrid.vat INFO value = 1

Grid: setwindow AEROZONE
Grid: setcell minof
Grid: housezone = zonalsum(AEROZONE,HOUSEGRID)
Grid: house_resamp = resample(HOUSEZONE,2000)
Grid: hz_int = int(house_resamp)
    Make it a poly cov
Grid: house51_cov = gridpoly(hz_int)
    Now take a look at this in AE and see how it looks.
        Looks good. This value can remain unitless since the ultimate objective will be to get the % of this surrogate in the cell for a given county. Not sure just yet how to get this value into the surrogate cov. Will leave as is for now, get rid of the grids, and go on.

I am not going to do a rural classification, since I don't have anything classifying it as such. Do a number of classes now.

Arc: tables
Tables: sel AERO_3_LU.pat
Tables: calc urb = 0
Tables: resel aero-lu = 1
388 Records Selected.
Tables: calc urb = 1
Tables: asel
Tables: calc DECIDG = 0
Tables: resel AERO-LU = 4 or AERO-LU = 5 or AERO-LU = 6
1562 Records Selected.
Tables: calc DECIDG = 1
Tables: asel
Tables: calc ag = 0
Tables: resel aero-lu = 2
645 Records Selected.
Tables: calc ag = 2
Tables: asel
Tables: calc watg = 0
Tables: resel aero-lu = 7
1033 Records Selected.
Tables: calc watg = 1
Tables: calc watg = 7
    ok
Tables: sel
Tables: copy AERO_3_LU.PAT surgat.join
    Drop unnecessary items

Arc: tables
Tables: sel surgat.join
Tables: alter DECIDG
COLUMN   ITEM NAME   WIDTH OUTPUT TYPE N.DEC ALTERNATE NAME
   9 DECIDG   4   8   B   -
Item Name: forest

Now add them to the surrogate cover.

Go back now and get the housing into the surrogate coverage.
Arc: tables
Tables: sel HOUSE51_COV.pat
Tables: alter grid-code
Item Name: housing

Arc: identity HOUSE51_COV ../AERO3_2KM houses2_cov
Get rid of some items
Looks good in AE
Arc: tables
Tables: copy HOUSES2_COV.pat house.join
Drop unneeded items
Arc: joinitem SCC_COV1.pat house.join SCC_COV1.pat cell-id

5/16/00

Now, need to get airports, railroads, and highways in the mix.
Start with highways.

Arc: copy UDOT_AERO highway_scc
Now eliminate roads so that I just have major highways left.
Arc: clip HIGHWAY_SCC ../state_clp3 HIGHWAY_SCC2 line
Arc: killem HIGHWAY_SCC
Arc: identity HIGHWAY_SCC2 SCC_COV1 HIGHWAY_SCC3 line
Now get rid of all the items I don't need and create a join file for scc_cov1
Tables: copy HIGHWAY_SCC3.aat highway.join
Get rid of the items
Arc: tables
Tables: sel highway.join
Tables: alter length
Item Name: highwaylength

Arc: frequency highway.join highway.frq
Enter Frequency item names (type END or a blank line when done):
==
Enter the 1st item: cell-id
Enter the 2nd item: end

Enter Summary item names (type END or a blank line when done):
==
Enter the 1st item: highwaylength

Enter the 2nd item: end

Arc: joinitem SCC_COV1.pat highway.frq SCC_COV1.pat cell-id
Arc: killem HIGHWAY_SCC2 HIGHWAY_SCC3

Now do airports and railroads
Arc: import cover trair airport
Arc: import cover trrrd railroad

Arc: clip airport ../state_clp3 airport2 line
Arc: clip railroad ../state_clp3 railroad2 line

Arc: additem RAILROAD2.aat RAILROAD2.aat raillength 4 12 f 3
Arc: identity RAILROAD2 SCC_COV1 RAILROAD3 line
Now do a frequency
Arc: tables
Tables: sel RAILROAD3.AAT
Tables: calc raillength = length

Arc: frequency RAILROAD3.AAT rail.frq

Enter Frequency item names (type END or a blank line when done):
==
Enter the 1st item: cell-id
Enter the 2nd item: end

Enter Summary item names (type END or a blank line when done):
==
Enter the 1st item: raillength
Enter the 2nd item: end

Now join them
Arc: joinitem SCC_COV1.pat rail.frq SCC_COV1.pat cell-id

I still need to get some data from Steve P for airports. Also I will create a couple of new surrogates for POTWs and landfills which I will get from him to finish this coverage. Now, I will create the values of % that I need to use to create the output file.

First need to get a fips code attached to each cell.

Current location: /trinidad/uam_aero/ws.uamaero/ws.lu
Arc: tables
Tables: copy AERO_3_LU.pat fip.join
Tables: q
Get rid of the items I don't need
Arc: joinitem SCC_COV1.pat ../ws.lu/fip.join SCC_COV1.pat cell-id

Add all of the scc code items to scc_cov1. Call them scc50 etc.

Arc: additem SCC_COV1.pat SCC_COV1.pat scc50 5 5 n 3
etc.

5/17/00

I now have the % of all of the surrogates except for airports, POTWs, etc. I did this with the scc.aml in this directory. For urban forest I did the following:
Arcplot: clearsel
Arcplot: resel SCC_COV2 poly housing > 0
SCC_COV2 polys : 1133 of 7572 selected.
Arcplot: calc SCC_COV2 poly scc65 = scc51
Arcplot: q

Now wait to get the final data from Steve P.

5/27/00

POTW's are done. In POTWLL coverage.

Airports done. In AIRPOLYLL coverage.

6/2/00

Doin' dumps. The surrogate for landfills is created in dump.aml. The logic and method should be apparent there.

Thats done. One little detail to work out on 1 SL dump. Other than that it looks good.

6/8/00

Now it is time to sew these all together into a surrogate polygon coverage or really a .pat file that I will eventually unload. I think all of the various coverages I need to do this should be here in ws.surrogate.

Get my starting coverage.
Arc: copy ../AERO_3_FIP surrogate1

Get column and row items and attributes set. This is done with colrow.aml.
Done

Let me list the surrogates I need once again. This list of surrogates is the complete list of surrogates for mobile and area sources to be used with this running of SMOKE for the 1996 February episode.

SSC	Description	
50	Population	
51	Housing	
52	Inverse Housing	(not used)
53	Inverse Population	(not used)
54	Rural	(not used)

55 Urban
60 Area
61 Forest
62 Agriculture
63 Water
64 Rural Forest (not used)
65 Urban Forest (not used)
71 Airports
72 Highways
73 Ports (not used)
74 Railroads
Next 6 are added by me
80 POTW
81 Land fills
10 local
20 freeway
30 ramp
40 arterial
41 rural arterial
42 Weber arterial
43 Weber local

The rural arterial is a separate surrogate because of the way vmt is reported by UDOT for the outlying counties. It is both put on a network and additional vmt is reported in the towns and outlying parts of the county.

Revamp scc_cov1 with all new surrogate % items
First drop the old then add the new

Arc: dropitem SCC_COV1.pat SCC_COV1.pat
Enter the 1st item: SCC50
Enter the 2nd item: etc...

Arc: additem SCC_COV1.pat SCC_COV1.pat ssc10 4 12 f 7
etc., etc.

Now add in all of the data needed for the other surrogates to this coverage then calculate the percentages and then add the row column data and this will be one complete coverage of the surrogate data needed to create the AGPRO/MGPRO file.

Attach the data
Airports
Tables: copy AIRPOLYLL.PAT air.join
Tables: sel air.join
Tables: alter percent

COLUMN	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	ALTERNATE NAME
5	PERCENT	5	6	N	2	

Item Name: ssc71
Drop all items except cell-id and percent
Arc: joinitem SCC_COV1.pat air.join SCC_COV1.pat cell-id

POTW
Tables: copy POTWLL.pat potw.join
Tables: sel potw.join
Tables: alter percent

COLUMN	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	ALTERNATE NAME
55	PERCENT	5	6	N	2	

Item Name: ssc80
Drop all items except cell-id and percent
Arc: joinitem scc_cov1.pat potw.join scc_cov1.pat cell-id

Dumps
Tables: copy DUMP_PTS4.pat dump.join
Tables: sel dump.join
Tables: alter percent

COLUMN	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	ALTERNATE NAME
27	PERCENT	4	4	N	2	

Item Name: ssc81
Drop all items except cell-id and percent
Arc: joinitem scc_cov1.pat dump.join scc_cov1.pat cell-id

Mobile surrogates

This will be a different and more involved process to get the mobile surrogate into the coverage since they are arc coverages.
Start with the WF arterial, freeway and ramp surrogates.

6/12/00

...Instead of separating these classes into poly cov's I will make separate line covs for each road class using the PUT command in AE.

Mobile surrogates (cont.)

Freeways
Arc: ae;ec WF_ARTFRE3;ef arc;de arc;draw
Copyright (C) 1982-1999 Environmental Systems Research Institute, Inc.
All rights reserved.
ARCEDIT Version 8.0.1 (Fri Dec 3 10:45:59 PST 1999)

The edit coverage is now
/TRINIDAD/UAM_AERO/WS.UAMAERO/WS.SURROGATE/WF_ARTFRE3
WARNING the Map extent is not defined
Defaulting the map extent to the BND of
/TRINIDAD/UAM_AERO/WS.UAMAERO/WS.SURROGATE/WF_ARTFRE3
13221 element(s) for edit feature ARC
Coverage has no COGO attributes
Arcedit: sel ft = 1
923 element(s) now selected
Arcedit: put wf_fre
Creating /TRINIDAD/UAM_AERO/WS.UAMAERO/WS.SURROGATE/WF_FRE

Copying the arc(s) into
/TRINIDAD/UAM_AERO/WS.UAMAERO/WS.SURROGATE/WF_FRE...
923 arc(s) copied

ATERIALS
Arc: ae;ec WF_ARTFRE3;ef arc;de arc;draw
Copyright (C) 1982-1999 Environmental Systems Research Institute, Inc.
All rights reserved.
ARCEDIT Version 8.0.1 (Fri Dec 3 10:45:59 PST 1999)

The edit coverage is now
/TRINIDAD/UAM_AERO/WS.UAMAERO/WS.SURROGATE/WF_ARTFRE3
WARNING the Map extent is not defined
Defaulting the map extent to the BND of
/TRINIDAD/UAM_AERO/WS.UAMAERO/WS.SURROGATE/WF_ARTFRE3
13221 element(s) for edit feature ARC
Coverage has no COGO attributes
Arcedit: sel ft > 1 and ft < 7
11705 element(s) now selected
Arcedit: put wf_art
Creating /TRINIDAD/UAM_AERO/WS.UAMAERO/WS.SURROGATE/WF_ART
Copying the arc(s) into
/TRINIDAD/UAM_AERO/WS.UAMAERO/WS.SURROGATE/WF_ART...
11705 arc(s) copied
Arcedit: ec WF_ART;ef arc
The edit coverage is now
/TRINIDAD/UAM_AERO/WS.UAMAERO/WS.SURROGATE/WF_ART
11705 element(s) for edit feature ARC
Coverage has no COGO attributes
Arcedit: sel all
11705 element(s) now selected
Arcedit: statistics

Enter statistical expressions. Type END or blank line to end.
Statistics: sum perft2
Statistics: end
Record FREQUENCY SUM-PERFT2
1 11705 4.000000

RAMPS
Arcedit: sel ft = 7
593 element(s) now selected
Arcedit: put wf_ramp
Creating /TRINIDAD/UAM_AERO/WS.UAMAERO/WS.SURROGATE/WF_RAMP
Copying the arc(s) into
/TRINIDAD/UAM_AERO/WS.UAMAERO/WS.SURROGATE/WF_RAMP...
593 arc(s) copied
Arcedit: ec wf_ramp;ef arc
The edit coverage is now
/TRINIDAD/UAM_AERO/WS.UAMAERO/WS.SURROGATE/WF_RAMP
593 element(s) for edit feature ARC

Coverage has no COGO attributes
Arcedit: sel all
593 element(s) now selected
Arcedit: statistics

Enter statistical expressions. Type END or blank line to end.
Statistics: sum perft7
Statistics: end
Record FREQUENCY SUM-PERFT7
1 593 4.000000

These all look GOOD.

Now I have a separate coverage for freeway, arterial and ramps for the WF counties. Go back up to the method above and do the same prep process to get the surrogates finished.

But first do the **outlying** counties.

Freeway
Arc: ae;ec OUTLY_UDOT3;ef arc;de arc;draw
972 element(s) for edit feature ARC
Coverage has no COGO attributes
Arcedit: sel fc = 1
210 element(s) now selected
Arcedit: put outly_fre
Creating /TRINIDAD/UAM_AERO/WS.UAMAERO/WS.SURROGATE/OUTLY_FRE
Copying the arc(s) into
/TRINIDAD/UAM_AERO/WS.UAMAERO/WS.SURROGATE/OUTLY_FRE...
210 arc(s) copied
Arterial
Arcedit: sel fc = 2
756 element(s) now selected
Arcedit: put outly_art
Creating /TRINIDAD/UAM_AERO/WS.UAMAERO/WS.SURROGATE/OUTLY_ART
Copying the arc(s) into
/TRINIDAD/UAM_AERO/WS.UAMAERO/WS.SURROGATE/OUTLY_ART...
756 arc(s) copied
Arcedit: sel fc <> 1 and fc <> 2
6 element(s) now selected
Arcedit: list fc
Record FC
372 3
406 3
421 3
426 3
434 3
709 3
Arcedit: ec OUTLY_FRE
The edit coverage is now
/TRINIDAD/UAM_AERO/WS.UAMAERO/WS.SURROGATE/OUTLY_FRE
Arcedit: sel all

No edit feature selected
Arcedit: ef arc
210 element(s) for edit feature ARC
Coverage has no COGO attributes
Arcedit: sel all
210 element(s) now selected
Arcedit: statistics

Enter statistical expressions. Type END or blank line to end.
Statistics: sum perfc1
Statistics: end
Record FREQUENCY SUM-PERFC1
1 210 5.000000
Arcedit: ec outly_art
The edit coverage is now
/TRINIDAD/UAM_AERO/WS.UAMAERO/WS.SURROGATE/OUTLY_ART
Arcedit: ef arc;sel all
756 element(s) for edit feature ARC
Coverage has no COGO attributes
756 element(s) now selected
Arcedit: statistics

Enter statistical expressions. Type END or blank line to end.
Statistics: sum perfc2
Statistics: end
Record FREQUENCY SUM-PERFC2
1 756 9.000000

I'll do a QA on these by doing a frequency on each coverage of fips values. If the freeway cov has five fips and the arterial cov has nine fips things are good.

Yup. Looks good.

Now get the local surrogate. Actually, thats already been done.

The process now is to get all of the surrogates into 1 coverage. Here we go...

Arc: tables
Tables: copy WF_FRE.aat wffre.join
Tables: copy WF_ART.aat wfart.join
Tables: copy WF_RAMP.aat wframp.join
Tables: copy ALL_LOCAL.pat alllocal.join
Tables: copy OUTLY_ART.aat outlyart.join
Tables: copy OUTLY_FRE.aat outlyfre.join
Tables: copy web_art2.aat webart.join

Drop superfluous items in all of them. Leave only cell-id and the precentage name.

Now create frequency files for all of the join files created from aat's. This is because multiple arcs could be identitied with a single cell-id. Since percentages were created by taking the arc vmt over the county vmt for a road class, summing these percentages by cell-id, using frequency, will give the proper surrogate % for a county.

Arc: frequency WFFRE.JOIN wffre.frq

Enter Frequency item names (type END or a blank line when done):
==
Enter the 1st item: cell-id
Enter the 2nd item: end

Enter Summary item names (type END or a blank line when done):
==
Enter the 1st item: perft1
Enter the 2nd item: end

Same process gets done for wfart.join, wframp.join, outlyart.join, outlyfre.join, and webart.join.

Now join these up to scc_cov1
Arc: joinitem scc_cov1.pat WFFRE.FRQ scc_cov1.pat cell-id
Arc: joinitem scc_cov1.pat WFART.FRQ scc_cov1.pat cell-id
Arc: joinitem scc_cov1.pat WFRAMP.FRQ scc_cov1.pat cell-id
Arc: joinitem scc_cov1.pat ALLLOCAL.JOIN scc_cov1.pat cell-id
Arc: joinitem scc_cov1.pat OUTLYART.FRQ scc_cov1.pat cell-id
Arc: joinitem scc_cov1.pat OUTLYFRE.FRQ scc_cov1.pat cell-id
Arc: joinitem scc_cov1.pat WEBART.FRQ scc_cov1.pat cell-id

Ramps
Tables: sel scc_cov1.pat
7572 Records Selected.
Tables: alter PERFT7
COLUMN   ITEM NAME   WIDTH OUTPUT TYPE N.DEC ALTERNATE NAME
  142 PERFT7   4   12   F   7
Item Name: ssc30

Local
Tables: alter PERLOC
COLUMN   ITEM NAME   WIDTH OUTPUT TYPE N.DEC ALTERNATE NAME
  146 PERLOC   4   12   F   7
Item Name: ssc10

Rural Arterial
Tables: alter PERARTRURAL
COLUMN   ITEM NAME   WIDTH OUTPUT TYPE N.DEC ALTERNATE NAME
  150 PERARTRURAL   4   12   F   7
Item Name: ssc41

Weber Arterial
Tables: alter PER42
COLUMN   ITEM NAME   WIDTH OUTPUT TYPE N.DEC ALTERNATE NAME
  162 PER42   4   12   F   7
Item Name: ssc42

Freeway

First, add rural + WF
Tables: alter PERFT1

```
COLUMN   ITEM NAME       WIDTH OUTPUT  TYPE N.DEC  ALTERNATE NAME
  142  PERFT1              8    18     F      6
```

Item Name: ssc20

Arterial

Add rural + WF
Tables: calc PERFT2 = PERFT2 + PERFC2
Tables: alter perft2

```
COLUMN   ITEM NAME       WIDTH OUTPUT  TYPE N.DEC  ALTERNATE NAME
  150  PERFT2              8    18     F      6
```

Item Name: ssc40

Drop a few unnecessary items.

Two things are left to do. 1) Edit and rerun scc.aml to create the percentages for the remaining surrogates. 2) Create a final coverage for a final surrogate called Weber local. This is for mobile emissions from local roads outside the WFRC modeling domain in Weber County. These are vmt from UDOT.

Since I only have the corporate boundary of Huntsville outside the WFRC domain, but do not have TAZ population all the way to the Lake, I will put 75% of the surrogate west of Ogden population and 25% in Huntsville. Kip agrees that that is reasonable. Keep in mind that the UDOT local vmt is only about 10% of the Weber local vmt from the transportation demand model.

1. Edit and run scc.aml.
   Done

First I better do some QA

Ran qa.aml. Few small problems flagged with "problem" in qa.out.

After these are worked out do some visual checks.

2. Do the final Weber local surrogate - 43.

Arc: copy ../ws.pop/POP96_2KM ./web_loc

add an item to receive the % surrogate

In AE bring up back coverages so that I can tell where to put the local vmt surrogate between the populated area of Ogden and the lake and in Huntsville. Choose cells visually and put the correct percentages in the cells so that when they are added up they equal 1.

Done

Tables: copy WEB_LOC.pat webloc.join
Tables: sel webloc.join
7572 Records Selected.
Tables: alter per43

```
COLUMN   ITEM NAME       WIDTH OUTPUT  TYPE N.DEC  ALTERNATE NAME
   63  PER43             4    12     F      7
```

Item Name: ssc43

drop superfluous items.

Join 'em up
Arc: joinitem SCC_COV2.pat webloc.join SCC_COV2.pat cell-id

Now, go back and take care of the QA problems identified in qa.out and put all of the intermediate coverages into a ws.covs directory.

$$$$$$$$$$$$$$$$ LOOKS GOOD - SURROGATES ARE DONE $$$$$$$$$$$$$$$$$$$$$$

Qa.out shows that the surrogates all add up to 1 as they should. Next step is to create vizual qa's then create the mgpro/agpro ascii file.

6/15/00

The visual qa of local vmt showed me an error the source of which I found in the all-loc.aml in ws.mobile. I fixed that, reran it and now need to redo the local surrogate.

Current location: /trinidad/uam_aero/ws.uamaero/ws.surrogate/ws.covs
Arc: killem ALL_LOCAL

Current location: /trinidad/uam_aero/ws.uamaero/ws.surrogate
Arc: copy ../ws.mobile/ALL_LOCAL ./ALL_LOCAL
Tables: copy all_local.pat ALLLOCAL.JOIN
Tables: copy all_local.pat artrural.join
Drop the unnecessary items from each file.

Arc: dropitem SCC_COV2.pat SCC_COV2.pat

Enter item names (type END or a blank line when done):
==
Enter the 1st item: SSC41
Enter the 2nd item: SSC10
Enter the 3rd item: end

Arc: joinitem SCC_COV2.pat ALLLOCAL.JOIN SCC_COV2.pat cell-id
Arc: joinitem SCC_COV2.pat artrural.join SCC_COV2.pat cell-id

Tables: sel SCC_COV2.pat
Tables: alter PERLOC

```
COLUMN   ITEM NAME       WIDTH OUTPUT  TYPE N.DEC  ALTERNATE NAME
  170  PERLOC               4    12     F     7
```

Item Name: ssc10
Tables: alter PERARTRURAL

```
COLUMN   ITEM NAME       WIDTH OUTPUT  TYPE N.DEC  ALTERNATE NAME
  174  PERARTRURAL          4    12     F     7
```

Item Name: ssc41

Did it. Re-QA'd it. Looks good. Back to the visual QA.

6/16/00

Visual looks good. Now create the AGPRO and MGPRO files for SMOKE.

Do an aml, agpro.aml, to get the job done. Documentation, process and logic will be found in that aml.

SCC.AML

```
/* 5/17/00
/*
/* scc.aml - calculates the % of the remaining surrogate types in each
cell.
/* PB
/* adapted 6/13/00
/*
&echo &on

&if [exists scc_cov2 -cover ] &then
   kill scc_cov2 all
copy scc_cov1 scc_cov2
&s cov = scc_cov2
ap
clearsel

&s fil1 = fips
&s unit1 = [open %fil1% 0 -read]

&do n = 1 &to 15
   &type %n%
   &s fip = [read %unit1% readstatus]
   clearsel
   resel %cov% poly fips = %fip%

   statistics %cov% poly
   sum pop96         /* 1
   sum ag            /* 2
   sum urb           /* 3
   sum forest        /* 4
   sum watg          /* 5
   sum housing       /* 6
   sum highwaylength /* 7
   sum raillength    /* 8
   end
   [unquote '']
/*** NOW SET VARIABLES FOR THESE STATS
   &s sc50 = [show statistic 1 1]
   &s sc62 = [show statistic 2 1]
   &s sc55 = [show statistic 3 1]
   &s sc61 = [show statistic 4 1]
   &s sc63 = [show statistic 5 1]
   &s sc51 = [show statistic 6 1]
   &s sc72 = [show statistic 7 1]
   &s sc74 = [show statistic 8 1]

   &if %sc50% = 0 &then
      &goto jump1
   calc %cov% poly ssc50 = ( pop96 / %sc50% )
      &label jump1
   &if %sc62% = 0  &then
      &goto jump2
```

```
   calc %cov% poly ssc62 = ( ag / %sc62% )
      &label jump2
   &if %sc55% = 0 &then
      &goto jump3
   calc %cov% poly ssc55 = ( urb / %sc55% )
      &label jump3
   &if %sc61% = 0 &then
      &goto jump4
   calc %cov% poly ssc61 = ( forest / %sc61% )
      &label jump4
   &if %sc63% = 0 &then
      &goto jump5
   calc %cov% poly ssc63 = ( watg / %sc63% )
      &label jump5
   &if %sc51% = 0 &then
      &goto jump6
   calc %cov% poly ssc51 = ( housing / %sc51% )
      &label jump6
   &if %sc72% = 0 &then
      &goto jump7
   calc %cov% poly ssc72 = ( highwaylength / %sc72% )
      &label jump7
   &if %sc74% = 0 &then
      &goto jump8
   calc %cov% poly ssc74 = ( raillength / %sc74% )
      &label jump8

&end
&s close = [close %unit1%]
&echo &off
&return
```

DUMP.AML

```
/* 6/7/00
/* dump.aml
/* generates the dump points then id's the cov then gets the surrogate
/* and percent inside.
/*
&echo &on
&if [exists dump_pts -cover] &then
   kill dump_pts all

&if [exists dump_pts2 -cover] &then
   kill dump_pts2 all

&if [exists dump_pts3 -cover] &then
   kill dump_pts3 all

&if [exists dump_pts4 -cover] &then
   kill dump_pts4 all

generate dump_pts
input ll.csv
points
q

project cover dump_pts dump_pts2 /uam5/ws.daq/dd.prj.dd
```

```
project cover dump_pts2 dump_pts3 /uam5/ws.daq/dd2utm.prj2
build dump_pts3 point

additem dump_pts3.pat dump_pts3.pat surrogate 2 2 i
additem dump_pts3.pat dump_pts3.pat percent 4 4 n 2

identity dump_pts3 ../aero_3_fip dump_pts4 point

ap

&s cov = dump_pts4
/*&s fil1 = dumpfip.fi
/*&s unit1 = [open %fil1% 0 -read]

&s fil2 = dumpper.fi
&s unit2 = [open %fil2% 0 -read]

&do n = 1 &to 11
   &type %n%
/*   &s fip = [read %unit1% readstatus]
   &s per = [read %unit2% readstatus]
   clearsel
   resel %cov% point %cov%-id = %n%
   calc %cov% point surrogate = 81
   calc %cov% point percent = %per%
&end

q
&s close = [close -all]
&echo &off
killem dump_pts dump_pts2 dump_pts3
&return
```

COLROW.AML

```
/* 6/8/00
/* colrow.aml
/* This  adds column and row items to surrogate1
/*
/* P. Barickman
/*
/*&echo &on
&if [exists surrogate2 -cover] &then
   kill surrogate2 all
copy surrogate1 surrogate2
/*
/* add the column and row items

additem surrogate2.pat surrogate2.pat col 4 4 i
additem surrogate2.pat surrogate2.pat row 4 4 i

/* Do a couple of big ol' loops

ap
 &s jumprow = 4388900          /*** initialize a row jumper
&do a = 1 &to 113
   &s row = %a%
   clearsel
```

```
   &s jumpup = ( %jumprow% + 200 )
   resel surrogate2 poly box 348900 %jumprow% 481100 %jumpup%
   &s jumprow = ( %jumprow% + 2000 )
   calc surrogate2 poly row = %row%
&end                         /*** ends the a loop

&s movecol = 348900
&do b = 1 &to 67
   &s col = %b%
   clearsel
   &s moveover = ( %movecol% + 200 )
   resel surrogate2 poly box %movecol% 4388900 %moveover% 4613100
   &s movecol = ( %movecol% + 2000 )
   calc surrogate2 poly col = %col%
   &end             /*** ends b loop
q
/*&echo &off
&return
```

ALLLOC.AML

```
/* 6/5/00
/* wf-loc.aml
/* Calculates the % of a counties local vmt for each cell
/*
&echo &on

&if [exists all_local -cover] &then
   kill all_local all
copy ../ws.pop/pop96_2km all_local
&s cov = all_local
additem %cov%.pat %cov%.pat perloc 4 12 f 7
additem %cov%.pat %cov%.pat perartrural 4 12 f 7
additem %cov%.pat %cov%.pat surrogate 2 2 i
additem %cov%.pat %cov%.pat surrogate2 2 2 i
/*
/* surrogate2 is an item to attribute the rural arterial ssc code
ap
clearsel

&s fil1 = wffip
&s unit1 = [open %fil1% 0 -read]

&do n = 1 &to 4              /* WF counties
   &type %n%
   &s fip = [read %unit1% readstatus]
   clearsel
   resel %cov% poly fips = %fip%

   statistics %cov% poly
   sum pop96
   end
   [unquote '']

   &s loc = [show statistic 1 1]
```

```
   calc %cov% poly perloc = pop96 / %loc%
   calc %cov% poly surrogate = 10
   clearsel
&end

&s fil2 = outfip
&s unit2 = [open %fil2% 0 -read]


&do s = 1 &to 9           /* outlying, including rural arterial
   &type %s%
   &s fip = [read %unit2% readstatus]
   clearsel
   resel %cov% poly fips = %fip%

   statistics %cov% poly
   sum pop96
   end
   [unquote '']

   &s locrur = [show statistic 1 1]

   calc %cov% poly perloc = pop96 / %locrur%
   calc %cov% poly perartrural = pop96 / %locrur%
   calc %cov% poly surrogate = 10
   calc %cov% poly surrogate2 = 41

   clearsel
&end /* end s

&s close = [close -all]
&echo &off
q
&return
```

QA.AML

```
/* 6/13/00
/*
/* qa.aml See if the surrogate items add to 1.
/* PB
/*
/*&echo &on

&if [exists qa.out -file ] &then
   rm qa.out
&s cov = scc_cov2
ap
clearsel

&s fil1 = fips
&s unit1 = [open %fil1% 0 -read]

&s unit2 = [open qa.out openstat -write]

&do n = 1 &to 15
   &type %n%
   &s fip = [read %unit1% readstatus]
```

```
   &s writestat = [write %unit2%  %fip%]
   clearsel
   resel %cov% poly fips = %fip%

   statistics %cov% poly
   sum ssc50         /* 1
   sum ssc51         /* 2
   sum ssc55           /* 3
   sum ssc61        /* 4
   sum ssc62          /* 5
   sum ssc63       /* 6
   sum ssc65      /* 7
   sum ssc72    /* 8
   sum ssc73       /*9
   sum ssc74       /*10
   sum ssc71       /*11
   sum ssc80       /*12
   sum ssc81       /*13
   sum ssc20       /*14
   sum ssc40       /*15
   sum ssc30       /*16
   sum ssc10       /*17
   sum ssc41       /*18
   sum ssc42       /*19
   sum ssc43       /*20
   end
   [unquote ]
/*** NOW SET VARIABLES FOR THESE STATS
   &s sc50 = [show statistic 1 1]
   &s writestat = [write %unit2% [quote sc50 = %sc50%]]
   &s sc51 = [show statistic 2 1]
   &s writestat = [write %unit2% [quote sc51 = %sc51%]]
   &s sc55 = [show statistic 3 1]
   &s writestat = [write %unit2% [quote sc55 = %sc55%]]
   &s sc61 = [show statistic 4 1]
   &s writestat = [write %unit2% [quote sc61 = %sc61%]]
   &s sc62 = [show statistic 5 1]
   &s writestat = [write %unit2% [quote sc62 = %sc62%]]
   &s sc63 = [show statistic 6 1]
   &s writestat = [write %unit2% [quote sc63 = %sc63%]]
   &s sc65 = [show statistic 7 1]
   &s writestat = [write %unit2% [quote sc65 = %sc65%]]
   &s sc72 = [show statistic 8 1]
   &s writestat = [write %unit2% [quote sc72 = %sc72%]]
   &s sc73 = [show statistic 9 1]
   &s writestat = [write %unit2% [quote sc73 = %sc73%]]
   &s sc74 = [show statistic 10 1]
   &s writestat = [write %unit2% [quote sc74 = %sc74%]]
   &s sc71 = [show statistic 11 1]
   &s writestat = [write %unit2% [quote sc71 = %sc71%]]
   &s sc80 = [show statistic 12 1]
   &s writestat = [write %unit2% [quote sc80 = %sc80%]]
   &s sc81 = [show statistic 13 1]
   &s writestat = [write %unit2% [quote sc81 = %sc81%]]
   &s sc20 = [show statistic 14 1]
   &s writestat = [write %unit2% [quote sc20 = %sc20%]]
   &s sc40 = [show statistic 15 1]
```

```
   &s writestat = [write %unit2% [quote sc40 = %sc40%]]
   &s sc30 = [show statistic 16 1]
   &s writestat = [write %unit2% [quote sc30 = %sc30%]]
   &s sc10 = [show statistic 17 1]
   &s writestat = [write %unit2% [quote sc10 = %sc10%]]
   &s sc41 = [show statistic 18 1]
   &s writestat = [write %unit2% [quote sc41 = %sc41%]]
   &s sc42 = [show statistic 19 1]
   &s writestat = [write %unit2% [quote sc42 = %sc42%]]
   &s sc43 = [show statistic 20 1]
   &s writestat = [write %unit2% [quote sc43 = %sc43%]]
&end
&s close = [close -all]
q
/*&echo &off
&return
```

AGPRO.AML

```
/* 6/16/00
/*
/* agpro.aml Prepares a coverage to output surrogate data for SMOKE.
/* PB
/*
/*
/*&echo &on

&if [exists scc_cov3 -cover ] &then
   kill scc_cov3 all
copy scc_cov2 scc_cov3
&if [exists agpro.out -file] &then
   rm agpro.out
&s cov = scc_cov3
additem %cov%.pat %cov%.pat coscty 6 6 i
additem %cov%.pat %cov%.pat col 4 4 i
additem %cov%.pat %cov%.pat row 4 4 i

/* Do a couple of big ol' loops

ap
 &s jumprow = 4388900          /*** initialize a row jumper
&do a = 1 &to 113
   &s row = %a%
   clearsel
   &s jumpup = ( %jumprow% + 200 )
   resel %cov% poly box 348900 %jumprow% 481100 %jumpup%
   &s jumprow = ( %jumprow% + 2000 )
   calc %cov% poly row = %row%
&end                          /*** ends the a loop

&s movecol = 348900
&do b = 1 &to 67
   &s col = %b%
   clearsel
   &s moveover = ( %movecol% + 200 )
   resel %cov% poly box %movecol% 4388900 %moveover% 4613100
   &s movecol = ( %movecol% + 2000 )
```

```
   calc %cov% poly col = %col%
&end             /*** ends b loop

clearsel

&s fil1 = fips
&s unit1 = [open %fil1% 0 -read]

&do n = 1 &to 15
   &type %n%
   &s fip = [read %unit1% readstatus]
   clearsel
   resel %cov% poly fips = %fip%
      &if %fip% < 10 &then
        calc %cov% poly coscty = 04900%fip%
      &else calc %cov% poly coscty = 0490%fip%
&end
q

tables
sel %cov%.pat
&s fil2 = ssc.fi
&s unit2 = [open %fil2% 0 -read]

&do o = 1 &to 20
   &type %o%
   &s ssc = [read %unit2% readstatus]
   resel ssc%ssc% > 0
   unload agpro.out %ssc% coscty col row ssc%ssc%
   asel
&end   /* ends o
q
/*&echo &off
&s close = [close -all]
&return
```

10.2 Chapter 3 Appendix B: Temporal Profile Development

Category	SCC	SCC Description	CARB Monthly Profile	EPA Weekly Profile	EPA Diurnal Profile	EPA Profile Explanation	Recommended Monthly Profile	Recommended Weekly Profile	Recommended Diurnal Profile	Justification for selected profile
Combustion of Wood, coal, oil, natural gas, diesel, gasoline, and/or wastes										
Fireplace and wood stove usage										
	A2104008000	residential wood stoves and fireplaces	None	7	33	7 day/wk-equal activity, increased activity early morning and evening.	20	7	33	Consistent with expected fireplace usage in residential areas.
Residential heating										
	A2104001000	anthracite coal	None	7	33	7 day/wk-equal activity, increased activity early morning and evening.	1	7	600	Increased activity in morning and evening hours when residences are occupied. Additionally, during the night when temperatures drop, fuel usage would increase. Recommended profile: 5pm - 8am weight of 8, 9am-4pm weight of 5. Created new profile 600.
	A2104002000	bituminous/sub. coal	None	7	33		1	7	600	
	A2104004000	distillate oil	1	7	33		1	7	600	
	A2104005000	residual oil	1	7	33		1	7	600	
	A2104006000	natural gas	None	7	33		1	7	600	
	A2104007000	LPG	None	7	33		1	7	600	
Industrial and commercial fuel combustion										
	A2102001000	industrial anthracite coal	None	7	24	7 day/wk-equal activity, 24 hr/day equal activity	1	22	602	Created new profile 602. Use 1/22/602 profile consistent with all fuel types.
	A2102002000	industrial bituminous/sub. Coal	None	22	37	Higher activity M-F with some activity sat/sun. Peak activity between	1	22	602	Majority of industrial activity takes place during normal business hours. Activity would most likely occur 24 hours per day with peak activity from 7 am - 5 pm. Higher
	A2102004000	industrial distillate oil	1	22	37		1	22	602	
	A2102005000	industrial residual oil	1	22	37		1	22	602	
	A2102006000	industrial natural gas	None	22	37		1	22	602	
	A2102007000	industrial LPG	None	22	37		1	22	602	

	A2102008000		industrial wood	None	22	37	9am-4pm and 0 activity between 9pm-5am.	1	22	602	combustion activity would occur during winter months.
	A2102009000		industrial coke	None	22	37		1	22	602	
	A2102010000		industrial process gas	None	22	37		1	22	602	
	A2103001000		commercial anthracite coal	None	22	37		1	22	602	
	A2103002000		commercial bituminous/sub. coal	None	22	37		1	22	602	
	A2103004000		commercial distillate oil	1	22	37	Higher activity M-F with some activity sat/sun. Peak activity between 9am-4pm and 0 activity between 9pm-5am.	1	22	602	Majority of industrial activity takes place during normal business hours.Activity would most likely occur 24 hours per day with peak activity from 7 am - 5 pm. Higher combustion activity would occur during winter months.
	A2103005000		commercial residual oil	1	22	37		1	22	602	
	A2103006000		commercial natural gas	None	22	37		1	22	602	
	A2103007000		commercial LPG	None	22	37		1	22	602	
	A2103008000		commercial wood	None	22	37		1	22	602	
	A2103011000		commercial kerosene	None	22	37		1	22	602	
Commercial cooking											
	A2222222222		No SCC found in reference list. Created a dummy SCC and appropriate profile.	None	7	24	7 day/wk-equal activity, 24 hr/day equal activity	21	7	24	Commercial food preparation/restaurants operate continuously.
Waste burning											
	A2610010000		industrial	None	22	37	Higher activity M-F with some activity sat/sun. Peak activity between 9am-4pm and 0 activity between 9pm-5am.	21	22	24	Majority of activity takes place during normal business hours. However, this activity assumes such activities as flares, which could happen anytime. Therefore, recommend a 24-hour profile.
	A2610020000		commercial/ institutional	None	7	37	7 day/wk-equal activity, Peak activity between	21	7	37	Commercial waste burning activities would take place 7days/week during normal business hours.

							9am-4pm and 0 activity between 9pm-5am.				
	A2610030000		residential	None	7	37	7 day/wk-equal activity, Peak activity between 9am-4pm and 0 activity between 9pm-5am.	22 or 35	7	37	Expect fires to burn continuously, however not for extended periods of time. R307-202-5 specifies a 30-day open burning period between March 30 and May 30 to be established by the local fire marshal for SL, DV, WB & UT Counties, or a 30 day period established by the State Forester in areas outside SL, DV, WB, & UT Counties between Sept. 15 and Oct. 30.
Uncontrolled Fires											
Structural fires											
	A2810030000		combustion/ structural fires/ total	None	7	24	7 day/wk-equal activity, 24 hr/day equal activity	32	7	24	Expect fires to burn continuously, however not for extended (monthly) periods of time. Monthly profile based on Utah Fire Incident Reporting System.
Car fires											
	A2810050000		combustion/ motor vehicle fires/total	None	7	37	7 day/wk-equal activity, Peak activity between 9am-4pm and 0 activity between 9pm-5am.	33	7	99	Peak during morning and evening commute, not zero between 9pm and 5am. Always potential for car fire. Monthly profile based on Utah Fire Incident Reporting System.
Off-road Mobile Sources and Miscellaneous Equipment											
Commercial and military aircraft											

	A2275001000		military aircraft total	1	22	37	Higher activity M-F with some activity sat/sun. Peak activity between 9am-4pm and 0 activity between 9pm-5am.	21	22	37	Majority of military training flights occur during normal business hours. (At Hill AFB evening and night flights are minimal)
	A2275020000		commercial aircraft total	1	22	37	Higher activity M-F with some activity sat/sun. Peak activity between 9am-4pm and 0 activity between 9pm-5am.	21	22	601	Majority of commercial flights occur during normal business hours. However some flights do occur outside of the default profile. Recommend a profile as follows: 6am to 10pm weight of 10, 11pm to 5 am weight of 8. Created new profile 601.
Airport grounds equipment and vehicles											
	A2270008000		diesel	1	22	37	Higher activity M-F with some activity sat/sun. Peak activity between 9am-4pm and 0 activity between 9pm-5am.	21	22	601	Majority of activity takes place during normal business hours. Ground equipment should have a profile consistent with aircraft operations. Recommend a profile as follows: 6am to 10pm weight of 10, 11pm to 5 am weight of 8. Created profile new 601.
	A2265008000		gasoline	1	22	37	Higher activity M-F with some activity sat/sun. Peak activity between	21	22	601	Majority of activity takes place during normal business hours. Ground equipment should have a profile consistent with aircraft operations. Recommend a profile

							9am-4pm and 0 activity between 9pm-5am.				as follows: 6am to 10pm weight of 10, 11pm to 5 am weight of 8. Created new profile 601.
Industrial and commercial equipment and vehicles											
	A2270003000		industrial diesel	1	5	37	M-F activity with 0 sat/sun. Peak activity between 9am-4pm and 0 activity between 9pm-5am.	21	5	37	Support functions, shipping operations etc. would operate during normal business hours.
	A2265003000		industrial gasoline	1	5	37	M-F activity with 0 sat/sun. Peak activity between 9am-4pm and 0 activity between 9pm-5am.	21	5	37	Support functions, shipping operations etc. would operate during normal business hours
	A2270006000		light commercial diesel	1	22	37	Higher activity M-F with some activity sat/sun. Peak activity between 9am-4pm and 0 activity between 9pm-4am.	21	22	37	Majority of activity would be conducted during normal business hours.
	A2265006000		light commercial gasoline	1	22	37	Higher activity M-F with some activity sat/sun. Peak activity	21	22	37	Majority of activity would be conducted during normal business hours.

							between 9am-4pm and 0 activity between 9pm-4am.				
Railroads											
	A2285002000		total railroads diesel	1	22	20	Higher activity M-F with some activity sat/sun. Activity equally spaced between 3am-10 pm with 0 activity between 11pm and 2am.	21	22	20	Railroad usage would likely not be zero between 11pm and 2 am. Recommend a profile of 1/7/24.
	A2285002005		line haul locomotive diesel	1	22	20		21	22	20	
	A2285002010		yard haul diesel	1	22	20		21	22	20	
Commercial fishing											
	A2280001030		coal	1	7	24	7 day/wk-equal activity, 24 hr/day equal activity	26	7	24	During the open seasons, fishing activities would be conducted continuously. Brine shrimp harvest October through January.
	A2280002030		diesel	1	7	24		26	7	24	
	A2280003030		residual	1	7	24		26	7	24	
	A2280004030		gasoline	1	7	24		26	7	24	
Snowmobiles											
	A2265001020		4-stroke gasoline	16	21	70	Sat/Sun twice the activity as M-F. Increasing activity from 8am to 4 pm then decreasing until 10 pm.	16	21	70	Snowmobiling is a recreational activity which would be conducted primarily on the weekends, during daylight hours.
	A2260001020		2-stroke gasoline	16	21	70		16	21	70	
Snowblowers-handheld											
	A2265004035		4-stroke gasoline	None	7	37	7 day/wk-equal	23	7	37	Snowfall is not limited to any day of the

	A2260004035		2-stroke gasoline	None	7	37	activity, Peak activity between 9am-4pm and 0 activity between 9pm-5am.	23	7	37	week. Clearing of snow would likely be conducted throughout the day with minimal activity during late night hours.
	A2270004035		diesel	None	7	37		23	7	37	
Mineral / Other Process											
Sand and gravel excavation and processing											
	A2325030000		mining and quarrying/sand and gravel	None	5	37	M-F activity with 0 sat/sun. Peak activity between 9am-4pm and 0 activity between 9pm-5am.	3	5	37	Activities take place during normal business hours; larger facilities covered under point sources would likely operate on weekends.
Concrete production											
	A2305070000		concrete, gypsum, plaster, total	None	5	37	M-F activity with 0 sat/sun. Peak activity between 9am-4pm and 0 activity between 9pm-5am.	3	5	37	Activities take place during normal business hours; larger facilities covered under point sources would likely operate on weekends.
Surface blasting											
	A2325000000		industrial process/mining and quarrying/all processes	None	5	37	M-F activity with 0 sat/sun. Peak activity between 9am-4pm and 0 activity between 9pm-5am.	3	5	37	These sources are likely to be small (non-point source) therefore extended operations were assumed to be minimal.

Metal processing											
	A2303000000		primary metal - total	None	5	37	M-F activity with 0 sat/sun. Peak activity between 9am-4pm and 0 activity between 9pm-5am.	21	5	37	Activities take place during normal business hours.
	A2304000000		secondary metal - total	None	5	37		21	5	37	Activities take place during normal business hours.
Wood processing											
	A2307000000		all wood processes total	None	5	37	M-F activity with 0 sat/sun. Peak activity between 9am-4pm and 0 activity between 9pm-5am.	21	5	37	Activities take place during normal business hours.
Evaporative or Direct Emissions of VOC's											
Chemical processes											
	A2301000000		chemical manufacturing/SIC 28/all processes total	None	5	37	M-F activity with 0 sat/sun. Peak activity between 9am-4pm and 0 activity between 9pm-5am.	21	5	37	Activities take place during normal business hours.
	A2510000000		organic chemical storage/all storage types breathing/all products	None	7	24	7 day/wk-equal activity, 24 hr/day equal activity	21	7	24	Industrial operations would be conducted on a continuous basis.
	A2510995000		organic chemical storage/all storage types working/all products	None	7	24	7 day/wk-equal activity, 24 hr/day	21	7	24	Industrial operations would be conducted on a continuous basis.

							equal activity				
	A2515000000		organic chemical storage/all transport types /all products	None	7	24	7 day/wk-equal activity, 24 hr/day equal activity	21	7	24	Industrial operations would be conducted on a continuous basis.
Bakeries											
	A2302050000		No SCC for Bakeries. Used Industrial food and kindred products total	None	6	40	M-Sat. activity closed Sunday. Peak activity between 3am-12pm.	21	6	40	Baking activities generally take place Monday -Saturday with baking hours from 3am to 12pm. Based on local bakeries contacted.
Petroleum loading storage and transportation											
	A2501000000		petroleum product storage/all storage types breathing/all products	None	7	24	7 day/wk-equal activity, 24 hr/day equal activity	21	7	24	Loading and storage operations would be conducted on a continuous basis.
	A2501995000		petroleum product storage/all storage types working/all products	None	7	24	7 day/wk-equal activity, 24 hr/day equal activity	21	7	24	Loading and storage operations would be conducted on a continuous basis.
	A2505000000		petroleum product storage/all transport types /all products	None	7	24	7 day/wk-equal activity, 24 hr/day equal activity	21	7	24	Loading and storage operations would be conducted on a continuous basis.
	A2501050000		petroleum and petroleum product/bulk stations terminals/all products	None	7	24	7 day/wk-equal activity, 24 hr/day equal activity	21	7	24	Loading and storage operations would be conducted on a continuous basis.
	A2501060000		petroleum and petroleum product/gasoline service stations/all products	None	6	500	Equal Activity M-Sat.	21	7	24	Recommend a 1/7/24 profile. Equal activity 24 hours/day 7 days/week for a gasoline service station.

	A2501070000		petroleum and petroleum product/diesel service stations/all products	None	7	24	7 day/wk-equal activity, 24 hr/day equal activity	21	7	24	Loading and storage operations would be conducted on a continuous basis.
Dry cleaning											
	A2420000000		all process - all solvents - total	None	6	37	M-Sat. activity with 0 sun. Peak activity between 9am-4pm and 0 activity between 9pm and 5am.	21	6	37	Dry cleaners generally operate normal business hours Monday through Sat with actual cleaning activities following the same profile.
Solvent use											
	A2465100000		solvent use - consumer/all personal care products	None	7	33	Equal Activity M-Sun.	21	7	33	Personal care products would be used 7 days/week. During the day, higher weighted usage would occur in the morning and late evening hours to correspond with peoples daily activities. (Getting ready for work and bed.)
	A2465200000		solvent use - consumer/all household products	None	7	37	7 day/wk-equal activity, Peak activity between 9am-4pm and 0 activity between 9pm-5am.	21	7	37	Household product usage would take place 7 days/week. Activity would not likely occur during late night hours.
	A2465400000		solvent use - consumer/ automotive after-market products	None	7	37	7 day/wk-equal activity, Peak activity between 9am-4pm and 0 activity	21	7	37	Automotive after-market product usage would take place 7 days/week. Activity would not likely occur during late night hours.

							between 9pm-5am.				
	A2465600000		solvent use - consumer/all adhesives and sealant products	None	7	37	7 day/wk-equal activity, Peak activity between 9am-4pm and 0 activity between 9pm-5am.	21	7	37	Consumer usage of adhesives and sealant would take place 7 days/week. Activity would not likely occur during late night hours.
	A2461000000		commercial solvent use - all processes all products	None	6	37	M-Sat. activity with 0 sun. Peak activity between 9am-4pm and 0 activity between 9pm and 5am.	21	6	37	Commercial use of solvents would likely be conducted 6 days per week during the business day.
Printing											
	40588801		printing/publishing/fugitive	None	7	24	No profile was found for SCC. Assumed a 7 day/wk-equal activity, 24 hr/day equal activity.	21	7	24	Printing operations take place continuously. Profile was assumed based on actual operations of local print shop.
Construction and Demolition											
Road construction in the winter											
	A2311030000		total road construction	7	7	37	7 day/wk-equal activity, Peak activity between 9am-4pm and 0 activity between 9pm-5am.	34	6	37	Road construction generally takes place Monday through Saturday. Recommend changing profile to 6 day week; also change monthly activity per UDOT, no activity November through March.

Structural construction in the winter											
	A2311010000		general building construction	7	7	37	7 day/wk- equal activity, Peak activity between 9am-4pm and 0 activity between 9pm-5am.	29	6	37	Construction activities generally take place during day-time hours. Recommend changing profile to 6 day week and reducing wintertime activity.
	A2311020000		heavy construction total	7	7	37	7 day/wk- equal activity, Peak activity between 9am-4pm and 0 activity between 9pm-5am.	29	6	37	Construction activities generally take place during day-time hours. Recommend changing profile to 5 day week, 1/5/37.
Biogenic											
	A2701460000		natural sources/biogenic/soil wetlands	1	7	24	7 day/wk- equal activity, 24 hr/day equal activity	1	7	24	No SCC for ammonia emissions from wetlands. Used general wetland SCC.
POTW											
	50100799		POTW / other not classified	1	7	24	7 day/wk- equal activity, 24 hr/day equal activity	1	7	24	No SCC for general POTW's. Used general SCC and assumed a profile of 7 days/week 24 hours/day.
Agricultural Livestock Activities											
	A2805001000		misc. source/ag. production- livestock/beef cattle feedlot	None	7	24	7 day/wk- equal activity, 24 hr/day equal activity.	21	7	24	Feedlot operations are conducted continuously.
Additional Items from file <<pm10sipinventory2>>											
Industrial Surface Coating											

	all applicable		all	None	5	37	M-F activity with 0 sat/sun. Peak activity between 9am-4pm and 0 activity between 9pm-5am.	21	5	37	Industrial surface coating applications would be conducted M-F during normal business hours.
Auto body refinishing											
	A2401005000		surface coating/auto refinishing SIC 7532/total all solvent types	None	5	37	M-F activity with 0 sat/sun. Peak activity between 9am-4pm and 0 activity between 9pm-5am.	21	5	37	Autobody work would be conducted during normal business hours.
Graphic Arts											
	A2425000000		solvent utilization/graphic arts/ all process/total all solvent types	None	5	37	M-F activity with 0 sat/sun. Peak activity between 9am-4pm and 0 activity between 9pm-5am.	21	5	37	Work would be conducted during the normal business hours.
Landfills											
	A2620000000		waste disposal treatment and recovery/all categories/total (industrial/commercial/municipal)	None	7	24	7 day/wk-equal activity, 24 hr/day equal activity	21	7	24	Landfills are continuously exposed to the environment, consistent with a 7 day/wk, 24 hour/day profile.
LUST											

	A2501995000		storage & transport/pet. prod./all storage types:working/total all products	None	7	24	7 day/wk-equal activity, 24 hr/day equal activity	21	7	24	No exact match for category and SCC. Used closest SCC, consistent with a 7 day/wk, 24 hour/day profile.
Aircraft Rocket Engine Firing and Testing											
	A2810040000		misc. area sources/other combustion/aircraft/rocket engine firing and testing	None	7	37	7 day/wk-equal activity, Peak activity between 9am-4pm and 0 activity between 9pm-5am.	21	7	37	Work would be conducted during the normal business hours. Based on 1% of aircraft activities.